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FOR THE RECORD—A HISTORY OF THE NUCLEAR TEST PERSONNEL REVIEW PROGRAM, 1978-1986

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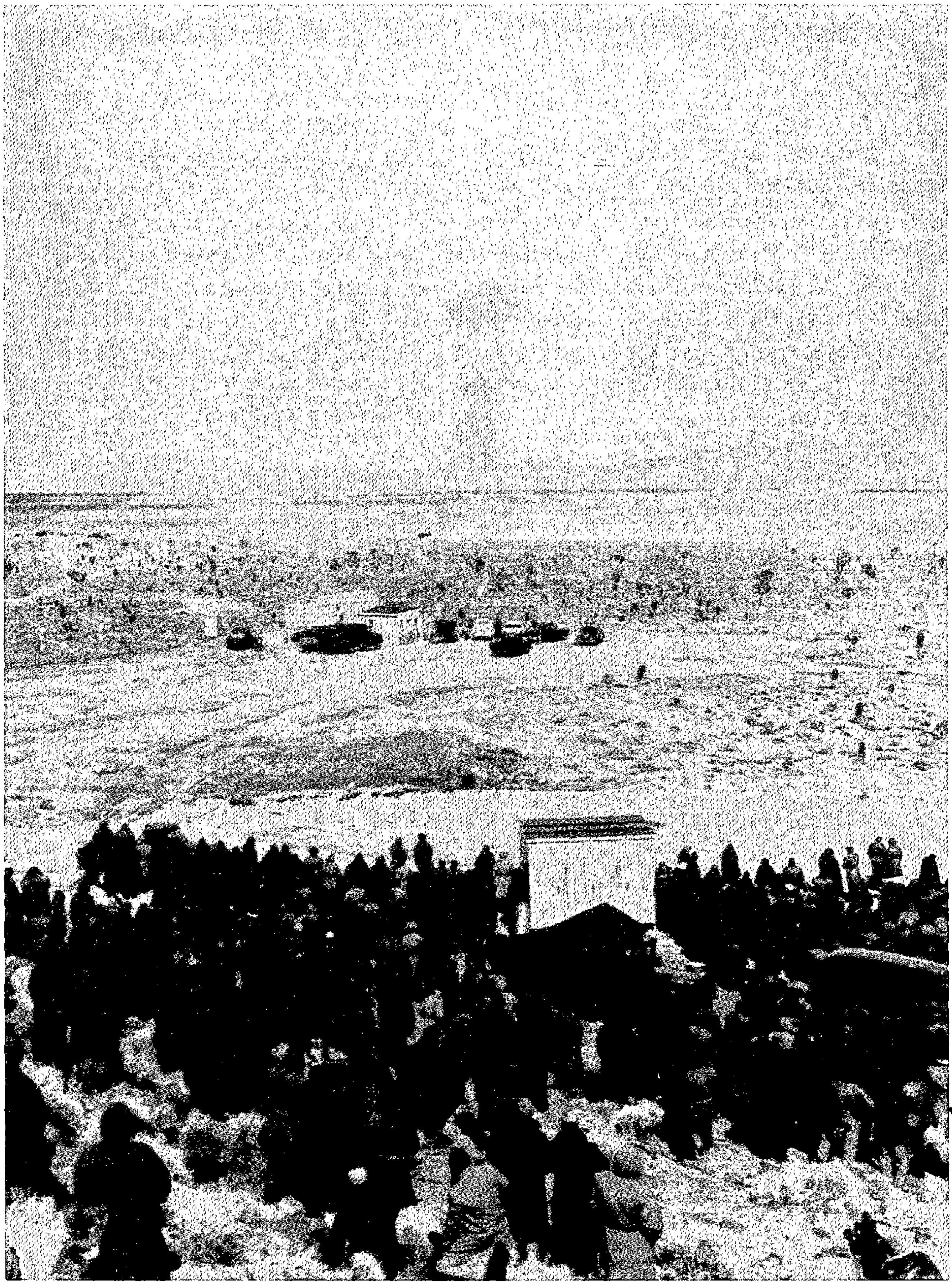

Observers watching the detonation of WASP, 18 February 1955, at a location about 15 kilometers from ground zero.

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PREFACE

The publication of For the Record: A History of the Nuclear Test Personnel Review Program, 1978-1986 marks the conclusion of the most active period of the Nuclear Test Personnel Review (NTPR) program, established by the Defense Nuclear Agency (DNA) in 1978. The volume has two purposes: (1) to provide the public with useful information concerning personnel participation in U.S. atmospheric nuclear testing and the postwar U.S. occupation of Hiroshima and Nagasaki, and (2) to provide a public accounting of the NTPR effort, which has involved a series of actions on behalf of the nuclear test participants and veterans of the Hiroshima and Nagasaki occupation. The text is directed to a diversified readership, including veterans, Congress, the media, and other interested parties.

For the Record attempts to serve the public by being relatively concise. This one volume synthesizes relevant information from a substantial number of published sources, including the 41-volume, 9,029-page history of atmospheric nuclear testing published earlier by the Defense Nuclear Agency. It also presents data elicited from unpublished sources, such as letters, memoranda, and speeches, and from interviews with NTPR personnel. Readers desiring additional information should consult the original sources, which are identified at the end of each chapter and in Appendices D through F.

The body of this history divides into three basic parts. Chapters 1, 2, and 3 introduce the NTPR program and highlight organizational contributions. Chapters 4 through 6 concentrate on the nuclear operations, describing the detonations, personnel participation, and radiation safety measures. Chapters 7 and 8 focus on radiation dose, the former on radiation dose determination and the latter on medical studies of potential dose effects.

Chapter 1, Introduction to the Defense Nuclear Agency and the NTPR Program, contains the heart of the book. It identifies the origins, scope, and accomplishments of the program and then presents a summary table of radiation doses for veterans of the nuclear tests and the Hiroshima/Nagasaki occupation.

Chapter 2, The Work of the NTPR Teams, highlights the NTPR efforts of the four military service teams and a separate team at DNA's Field Command in Albuquerque, New Mexico. While DNA directs the NTPR program, the five teams execute the assigned tasks. This chapter identifies the resources available to each team, in terms of both personnel and funds, and itemizes the results, including statistics on the assignment of doses and the notification of personnel concerning available medical examination programs.

Chapter 3, The NTPR Program, the Department of Energy, and the Veterans Administration, discusses the efforts of two Federal agencies that do not have NTPR organizations but make important contributions to the program, nonetheless. A Department of Energy (DOE) contractor, Reynolds Electrical & Engineering Company (REECo) of Las Vegas, Nevada, developed and maintains the official master file of dose records for the atmospheric nuclear weapons tests. DOE also established and administers the Coordination and Information Center (CIC), a public archives in Las Vegas housing 125,000 declassified documents pertinent to U.S. nuclear weapons testing. The Veterans Administration (VA) gives complete medical examinations upon request to veterans exposed to ionizing radiation during the nuclear tests or the U.S. occupation of Hiroshima and Nagasaki. It also provides health services and compensation benefits to veterans if they meet the specified criteria identified in chapter 3.

The most extensive part of the volume, with 21 sections, is Chapter 4, U.S. Nuclear Testing from Project TRINITY to the PLOWSHARE Program. This chapter surveys the test series from 1945 to the end of U.S. atmospheric nuclear testing, which came with the last Pacific test on 4 November 1962. The narrative delineates the background, purpose, and operations for each series, and it provides a summary of doses according to Service participation.

Chapter 5, Radiation Safety at the Atmospheric Nuclear Tests, is a companion to chapter 4. It discusses radiation safety at the nuclear tests, concentrating primarily on protective measures against exposure to initial and residual radiation and personnel contamination. The chapter identifies radiation detection/measurement instruments used for survey and/or personnel monitoring. It also indicates protective methods taken against internal doses that could result from the inhalation or ingestion of radioactive material.

Chapter 6 focuses not on the nuclear tests but on the U.S. postwar occupation of Japan. Entitled "The Atomic Bombing and U.S. Occupation of Hiroshima and Nagasaki," the chapter describes the detonations, the initial and residual radiation, and the participation and radiation doses of U.S. occupation troops. DNA expanded the NTPR program in 1979 to incorporate research and assistance efforts on behalf of the former occupation troops.

Chapter 7, Radiation Dose Determination, focuses on dose determination for both the veterans of nuclear testing and the Hiroshima/Nagasaki occupation. It discusses the use of film badge data from badged personnel to estimate individual doses for unbadged personnel. In addition, it presents the methods for dose reconstruction employed when film badge data were unavailable or unrepresentative of individual or group activities.

Chapter 8, Health Effects of Ionizing Radiation and Medical Followup Studies of Veterans, addresses two topics. It first discusses the health effects of ionizing radiation as generally understood by both national and international experts. The chapter then summarizes the epidemiological studies of the veterans of the nuclear tests and the Hiroshima/Nagasaki occupation. The studies have been conducted by the Centers for Disease Control, the Argonne National Laboratory, the National Research Council of the National Academy of Sciences, and the Office of Technology Assessment.

The six appendices are designed to assist the reader in using this volume and in conducting additional research. Appendix A, Chronology of Selected Events Relevant to the NTPR Program, highlights key information presented in the text. Appendix B, Glossary, defines technical and organizational terms pertinent to the commentary, and Appendix C lists abbreviations and acronyms. Appendix D, Public Resources for Documents on Atmospheric Nuclear Weapons Testing, discusses the availability of documents for purchase at the National Technical Information Service (NTIS) and for research at the Coordination and Information Center. Appendix E identifies the DNA personnel-oriented histories of atmospheric nuclear testing, all of which are for sale at NTIS and available for review at the CIC. The volume ends with Appendix F, Selected Bibliography, which specifies selected resources that should be available through major public and university libraries.

This volume quantifies program results in several places, particularly in Section 1.4, NTPR Program Accomplishments; Section 1.5, Summary of Radiation Doses; and in the "Results" sections of chapter 2; as well as in chapters 3 and 4. These statistics are current as of 1 May 1986, when research for this book was completed. As additional information becomes available, there may be minor adjustments to some of the numbers.

To facilitate the reading of this volume, the most current and commonly accepted names of locations and organizations are generally used throughout the text. Hence, the continental test site, which was called the Nevada Proving Ground from 1952 to 1955, is consistently referred to as the Nevada Test Site. Pacific Proving Ground is used as the designation of the primary oceanic site, which was also sometimes termed the Eniwetok Proving Ground or Bikini Proving Ground. In addition, the weapons development laboratories are cited by their present designations: Los Alamos National Laboratory (LANL), instead of Los Alamos Scientific Laboratory (LASL), as it was known earlier; and Lawrence Livermore National Laboratory (LLNL), rather than previous names, such as University of California Radiation Laboratory (UCRL).

A theme persists in For the Record. The purpose of the NTPR program is to provide information and assistance to the public, particularly to observers of and participants in atmospheric nuclear testing and in the Hiroshima/Nagasaki occupation. The accent of the Nuclear Test Personnel Review program has been, and continues to be, on personnel.

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SECTION 1

INTRODUCTION TO THE DEFENSE NUCLEAR AGENCY AND THE NTPR PROGRAM

The United States Government, primarily through the Manhattan Engineer District and its successor agency, the Atomic Energy Commission (AEC), conducted some 235 nuclear weapons tests from 1945 to 1962, during the atmospheric test series. The testing was principally in Nevada and the Pacific. An estimated 200,000 Department of Defense (DOD) personnel, military and civilian, took part in the tests, and many were exposed to low levels of ionizing radiation in the performance of various activities.

In March 1977, 15 years after the last above-ground nuclear test, the Veterans Administration (VA) office in Boise, Idaho, received a claim for disability benefits from retired Army Sergeant Paul R. Cooper. A patient at the VA hospital in Salt Lake City, Utah, Cooper attributed his acute myelocytic leukemia to the radiation exposure he had received as a participant in Shot SMOKY, conducted on 31 August 1957 as part of the 1957 series of nuclear tests, Operation PLUMBBOB. The VA initially denied Cooper's claim but later reversed its decision. The appeals board noted that sufficient signs of the disease had been present when Cooper was on active duty to support the claim as service connected. The board did not comment, however, on Cooper's assertion that his leukemia resulted directly from radiation exposure he had received at Shot SMOKY.

The VA decision on the Cooper claim initiated a series of events that ultimately involved the military services, the Defense Nuclear Agency (DNA), the Department of Energy (DOE), the National Academy of Sciences (NAS), the Department of Health and Human Services, and the White House. Questions fueling that involvement concerned, among other issues, the possible radiation doses received by test participants and the possible long-term health effects resulting from those doses.

This chapter describes the origins and the early history of the NTPR effort, when the program acquired its primary focus. Subsequent sections delineate the program's scope and accomplishments. The chapter concludes with a summary of radiation doses.

1.1 ORIGINS OF THE NTPR PROGRAM.

Through a series of meetings held in 1977, representatives of DOD, DOE, VA, and the Centers for Disease Control (CDC), among other agencies, concluded that research should be conducted concerning personnel participation in the U.S. atmospheric nuclear weapons test program. DOD and DNA representatives made commitments to establish an effort that would coordinate this research during hearings held by the Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce during 24-26 January and 14 February 1978. Their statements, along with decisions made during the 1977 meetings, laid a basis for the official establishment of the Nuclear Test Personnel Review (NTPR) in 1978.

An initial step was taken by the physician assigned in February 1977 to the Paul Cooper case at the Salt Lake City VA hospital. Concerned over the possibility of a connection between his patient's illness and his earlier participation in Shot SMOKY, the physician contacted Dr. Glyn G. Caldwell, Chief of the Cancer Branch of the Centers for Disease Control in Atlanta, Georgia. Dr. Caldwell, an epidemiologist who had an interest in leukemia studies, then contacted Dr. LaWayne R. Stromberg, Director of the Armed Forces Radiobiology Research Institute (AFRRI).* Dr. Caldwell informed Dr. Stromberg that he wanted to investigate the question of possible relationship between participation in a nuclear test and later development of cancer. Dr. Stromberg agreed to support the effort by attempting to retrieve dosimetry readings for the names of DOD personnel forwarded to him by Dr. Caldwell.

Shortly thereafter, the VA decided against Paul Cooper's claim. Sergeant Cooper then took his case to the media, which accorded him considerable attention. "Almost immediately the subject became a part of the public consciousness," to quote from a document tracing NTPR origins that was drafted by Paul H. Carew, DNA Comptroller. According to Carew, CDC received correspondence within a few days from "several dozen people" who claimed to have participated in the nuclear weapons tests. The number of letters increased to approximately 2,000 within 4 months (1).

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*AFRRI is a subordinate DNA organization responsible for studying the biological effects of ionizing radiation.

During March and April 1977, against the backdrop of increasing media attention, representatives from CDC, AFFRI, and the Office of the Surgeon General, U.S. Army, discussed the research effort proposed by Dr. Caldwell and the need for a mechanism to address relevant issues and process inquiries. With the support of the DNA Director, the Surgeon General of the Army appointed an ad hoc committee to coordinate a detailed review of troop participation in the atmospheric nuclear test program. Headed by Dr. Stromberg, the committee included representatives from various Army organizations, such as the Office of the Surgeon General, Office of the Deputy Chief of Staff for Operations and Plans, and Office of the Chief of Public Affairs. The committee convened on 6 May 1977 to formulate its goals and agenda (1).

On 13 May 1977, an AFRRI representative met with Dr. Caldwell at CDC in Atlanta to discuss the information CDC had and needed and to assess progress on the work undertaken. In reviewing his efforts, Dr. Caldwell noted that he had identified three confirmed cases of leukemia among the personnel who had written to CDC and indicated their participation in Shot SMOKY. This number was of interest to CDC because it was higher than expected for a comparable group. Dr. Caldwell had accordingly received CDC approval to conduct an epidemiological study of the entire SMOKY population. He required, however, a list of SMOKY participants complete with radiation exposure histories from DOD. Upon conclusion of the meeting, the AFRRI representative recommended that DOD provide the requested roster and data (1).

It soon became clear that the requisite data were incomplete and scattered in repositories across the country. To discuss data needs, as well as other concerns, a meeting of the ad hoc committee was scheduled for June 1977 at the DOE Nevada Operations Office (NVOO) in Las Vegas. NVOO was the center for testing activities at the Nevada Test Site (NTS) and a central archives for DOE information on the atmospheric test program (1).

Convened on 3 June 1977, the meeting involved 24 participants representing the Department of the Army, Department of Navy, DNA, DOE, Los Alamos National Laboratory (LANL), and Reynolds Electrical & Engineering Company (REECo), a DOE contractor at the NTS. The discussion focused on the availability of information, particularly from the REECo records indicating personnel exposures to ionizing radiation during the atmospheric nuclear tests. These records, discussed in section 3.1.1, provided useful information on personnel who had worn film badges. There were no entries, though, for the participants who did not wear film badges. The committee concluded that information would be needed to supplement the data made available by the REECo files and that cooperation would be required between the participants in the testing and CDC. The Army representatives supported this conclusion but announced they would proceed with a unilateral investigation of Army personnel at Shot SMOKY. They accordingly requested access to information on Army personnel exposures and related data as they were identified (1).

During the next 2 weeks, Major Alan L. Skerker, Office of the Deputy Chief of Staff for Operations and Plans, developed a roster for one of the Army contingents that had been at Shot SMOKY: the Provisional Company, 82nd Airborne Division. He recovered names from such sources as yearbooks housed at Fort Bragg, North Carolina. Individual dosimetry information came from records kept at the Lexington Bluegrass Signal Depot, Lexington, Kentucky. These data were sent on 15 June 1977 to Dr. Caldwell after the dose information had been removed according to constraints seemingly imposed by Public Law 93-579 of 1974, commonly known as the Privacy Act. It was later learned that the dose information could be provided to CDC (1).

By mid-August 1977, the ad hoc committee, which had been restructured to include the Surgeon General of the Air Force, the Surgeon General of the Navy, and the Department of Energy, had summarized its findings. It agreed to the following (1):

- That the concerned Federal agencies support Dr. Glyn Caldwell in his attempt to identify, locate, and obtain the necessary medical data on SMOKY participants
- That the ad hoc committee be established formally as an interagency committee with DOD, DOE, VA, and the U.S. Public Health Service as members
- That the review of DOD personnel exposure records associated with the nuclear weapons testing be continued.

On 3 November 1977, the interagency committee held a preliminary meeting to discuss the possible long-term health effects resulting from participation in atmospheric nuclear weapons testing. The attendees recommended that a major epidemiological study of test participants be undertaken under the direction of an independent scientific organization, such as the National Research Council (NRC) of the NAS, and that this effort be funded by DOD and DOE. They suggested, moreover, that a central administrative unit be established within DOD to coordinate all related activities. The final recommendation was for a meeting of senior officials of the concerned agencies, to be held as soon as possible, to organize the effort (1).

On 1 December 1977, the Assistant Secretary of Defense for Health Affairs convened a meeting to address the atmospheric nuclear weapons testing program and the possible relationship between participation in the program and an increased incidence of disease attributable to radiation exposure. Participants included representatives from the military services, DNA, DOE, VA, CDC, and the NRC, as well as epidemiological consultants from Walter Reed Army Medical Center. The meeting resulted in a decision to solicit a formal proposal for a study from NRC of the atmospheric nuclear test participants. It also resulted in the unofficial agreement that DNA would function as DOD executive agency for all matters pertaining to DOD personnel participation in the atmospheric nuclear test program (1; 2).

The Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce held hearings during 24-26 January and 14 February 1978 on DOD actions to collect data on DOD personnel who participated in atmospheric nuclear weapons testing. These hearings functioned as a catalyst for official establishment of the NTPR in late January 1978. In their testimony, DOD and DNA representatives not only highlighted the research initiated by concerned Federal agencies in 1977, but they made commitments to establish an effort that would develop histories of the atmospheric nuclear weapons tests, define radiation safety policies and procedures in effect during the tests, identify participation and radiation doses for DOD military and civilian personnel who took part in the tests, and make the resulting information available for review by scientific organizations. These commitments emerged as the primary NTPR tasks (3).

1.2 FOCUSING THE NTPR PROGRAM.

The early history of the NTPR program, like the beginnings of many other organizations, can be traced through memoranda drafted during the initial months of the effort. Most of the documents discussed in this section were written by or to Vice Admiral Robert R. Monroe, U.S. Navy, Director of the Defense Nuclear Agency from March 1977 to August 1980 and principal architect of the NTPR.

DNA responsibility for the NTPR officially started with two memoranda dated 28 January 1978 and signed by John P. White, Assistant Secretary of Defense, Manpower, Reserve Affairs, and Logistics. One of the documents, addressed to the Director of DNA, made the agency responsible for the following tasks and "for any others that may develop" (4):

- Develop a history of every atmospheric nuclear event that involved DOD personnel.
- Identify the radiation monitoring control policies, procedures, and requirements that were in effect.
- Assemble a census of personnel at each event. Identify their location, movements, protection, and radiation dose exposure.
- Make this information available for scientific review and appraisal.
- Handle public affairs matters in cooperation with the Office of the Assistant Secretary of Defense (Public Affairs).
- Handle Congressional Affairs matters in coordination with the Office of the Assistant to the Secretary of Defense for Legislative Affairs.

These tasks evolved over time, as indicated in section 1.3, but they were the basis of the NTPR effort.

The other 28 January 1978 memorandum was important because it gave the DNA Director "authority to task the Military Departments and other DOD elements and components" in responding to the assignments. This document was sent to the Secretaries of the Military Departments, the Chairman of the Joint Chiefs of Staff, and the Under Secretaries of Defense, among others (5).

Using his given authority, Vice Admiral Monroe delineated the respective responsibilities of DNA and the military services in a 13 February 1978 memorandum directed to the Secretary of the Army, the Secretary of the Navy, and the Secretary of the Air Force. DNA, he emphasized, would "organize and direct the overall effort," while each military service would be responsible for NTPR research pertinent to that service and for followup communications with service personnel (6).

DNA coordinated its approach with DOE and CDC in meetings held during March and April 1978. Representatives from DNA explained the NTPR program to DOE/NVOO and its contractors at a 9 March 1978 meeting. DOE hosted a meeting on 4 April 1978 that was attended by representatives of the DOD NTPR, National Archives, REECo, LANL, NAS/NRC, and each DNA contractor organization. The discussion focused on methods for identifying and obtaining records on atmospheric nuclear weapons testing (7).

An 8 June 1978 memorandum, drafted by Vice Admiral Monroe, directed the NTPR teams toward consistency in research. It asked them to collect the following information on test participants: "1) Full name (no initials), 2) Branch of service (if civilian, service/contractor/laboratory affiliation), 3) Unit or ship (at time of test), 4) Grade, rank, or rating (at time of test), 5) Service serial number(s), 6) Social security number, 7) Date of birth, 8) Shots participated in, 9) Radiation exposure data, in as much detail as possible (e.g.: total atmospheric test exposure; exposure by radiation type; exposure by shot, series, or time period; badge issue and turn-in dates; bioassay data; etc.), 10) Sources of above data elements." The memorandum also required the teams to research individual medical records, which would be a major effort involving considerable time. The rationale for this records search was as follows (8):

> First, the NTPR effort could scarcely be considered thorough, searching, or even competent if this basic source is not explored. Second, radiation exposure data is so central to the purpose of NTPR, and recorded information elsewhere is known to have such limitations, that no potential source can be overlooked. Third, since future research efforts (epidemiological, claims, etc.) will, in many cases, retrace this same ground, knowledge even of absence of information in medical records will be of considerable value. Finally, an understanding of the Services' past success or failure in recording exposures will be important in devising new systems.

With a memorandum dated 3 October 1979, DNA expanded the NTPR effort to include U.S. service personnel who had participated in the postwar occupation of Hiroshima and Nagasaki. Vice Admiral Monroe noted that the original NTPR charter had not included these personnel because the effort had been "limited to test participants" and the "wartime bombings were not tests." Nevertheless, he added, they had "the same need for DOD research and assistance" as did the former test participants. "Unless otherwise directed," he concluded, the NTPR program "is being expanded to include those U.S. servicemen who might have been exposed to low-level ionizing radiation as a result of the Hiroshima and Nagasaki bombings" (9). Vice Admiral Monroe was "so confident this step was right," he later explained, that he did not preface his statement to his superiors with "I recommend" (10).

The central management decisions emergent from the memoranda cited above and the other documents drafted in the early months of the NTPR effort were:

- To undertake the NTPR program as a major, multiyear, multimillion-dollar effort
- To organize the NTPR program with DNA exercising centralized guidance and the military services having responsibility for the execution of service research and followup with their own service personnel
- To pursue the NTPR program as a scientific and historical inquiry, producing factual results without regard to preconceptions or political acceptability
- To remain alert to any possible new requirement or any additional action that might seem needed and to modify the NTPR program accordingly.

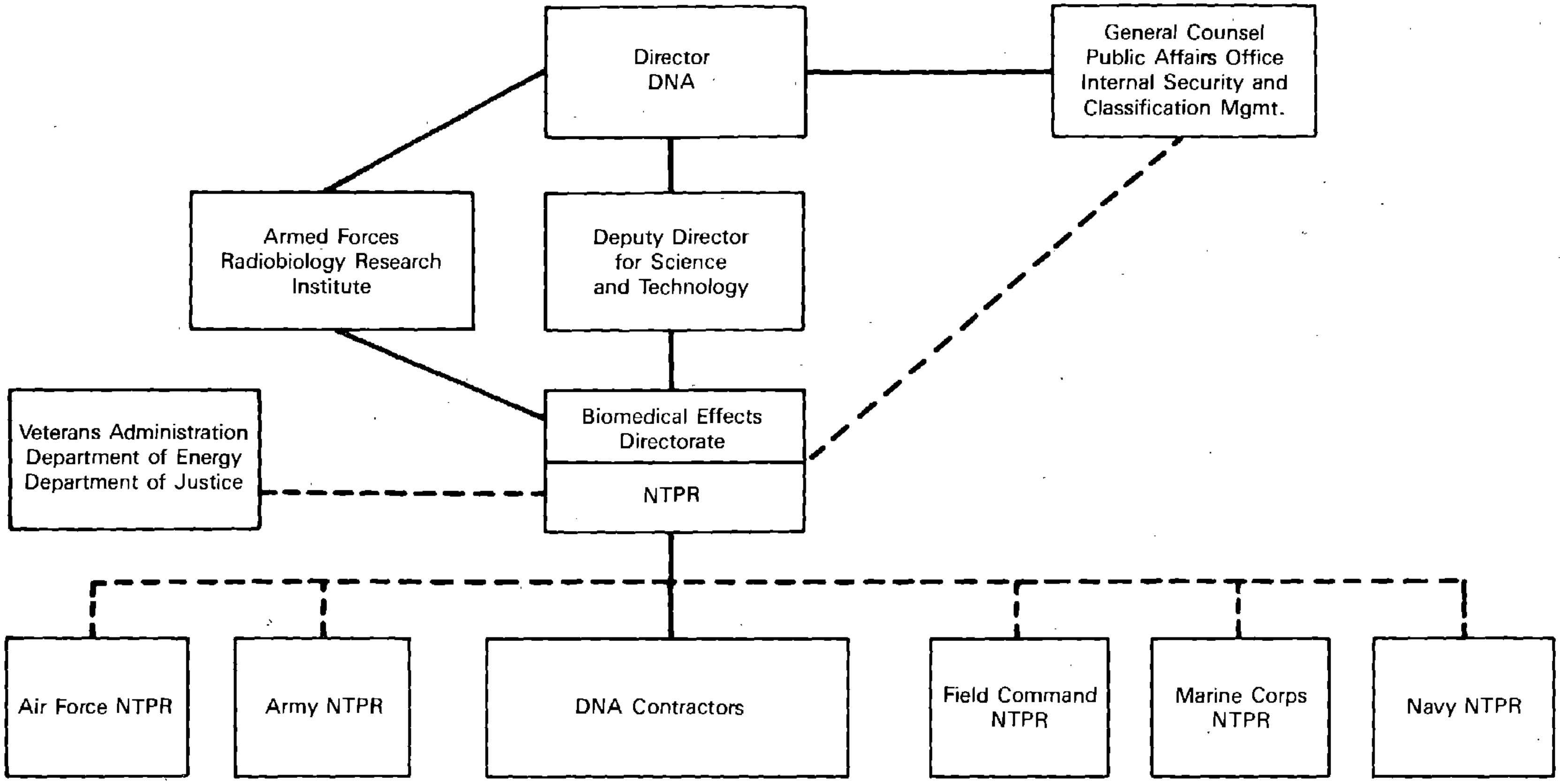
The last-mentioned decision resulted in a program that has evolved to meet the needs of the time (10).

1.3 SCOPE OF THE NTPR PROGRAM.

During the first 8 years of the program, the specific tasks of the NTPR have become more detailed and numerous. The 28 January 1978 memorandum cited in the preceding section itemized six tasks. Nine tasks eventually emerged, as listed below (11):

1. To compile a roster of the DOD personnel involved in the atmospheric nuclear tests
2. To develop a history of each atmospheric nuclear event that involved DOD personnel
3. To declassify all possible nuclear test related source documents that bore a security classification
4. To provide estimates of atmospheric test radiation doses--both as a check on film badge readings and as a substitute for them in those cases where badges were not worn or readings were not recorded or are not retrievable--and to submit the methodology for the estimates to the NAS for peer review
5. To establish personal contact with as many test participants as possible
6. To identify those individuals who received a higher radiation dose than those doses recommended under current Federal guidelines for radiation workers, to notify those individuals of their dose, and to offer veterans free medical examinations at Government hospitals
7. To sponsor, in conjunction with the Department of Energy, an independent mortality study by the National Academy of Sciences of test participants selected by the NAS
8. To carry out a detailed research program, in conjunction with the ongoing NTPR program, to recover all data pertaining to possible radiation exposure of U.S. postwar occupation troops at Hiroshima and Nagasaki, Japan
9. To provide assistance to the veteran, the Veterans Administration, and other organizations by doing research and by providing as complete data as possible on individual participation and radiation doses.

An NTPR team in each military service and a separate team at the DNA Field Command in Albuquerque, New Mexico, have worked with DNA in meeting these tasks, as is explained in chapter 2. In addition, DNA has employed several contractors to provide specialized supporting services. Figure 1 shows the basic organization of NTPR within DNA. The five NTPR teams and the contractors report to the NTPR Program Manager, who is responsible to the Director of DNA. Succeeding Vice Admiral Robert Monroe as DNA Director were Lieutenant General Harry A. Griffith, U.S. Army, August 1980 to August 1983;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Armed Forces
Radiobiology Research
Institute
Deputy Director
for Science
and Technology
Veterans Administration
Department of Energy
Department of Justice
Biomedical Effects
Directorate
NTPR
Air Force NTPR
Army NTPR
DNA Contractors
Field Command NTPR
Marine Corps NTPR
Navy NTPR

Figure 1. Organization of NTPR within DNA from 1982 to 1986.

Lieutenant General Richard K. Saxer, U.S. Air Force, August 1983 to June 1985; and Lieutenant General John L. Pickitt, U.S. Air Force, June 1985 to present.

1.4 NTPR PROGRAM ACCOMPLISHMENTS.

The NTPR program has been pursued on a high-priority basis, with adequate personnel support and funding. Table 1 shows NTPR Government and contractor person years from 1978 to 1986. Table 2 itemizes DNA and DOD annual NTPR funding for the same period (12; 13). This section presents the results achieved from these expenditures.

By 1 May 1986, the NTPR teams had identified by name approximately 90 percent of the estimated 200,000 DOD test participants and had recovered the dose information presented in table 4 (13). The effort is nearing completion on the first task, which is development of a roster of DOD participants in the nuclear tests. The roster will list participants and their radiation doses for each series.

The personnel-oriented history of the atmospheric test program, the second task, has been completed. This 9,029-page history comprises 41 volumes. The reports, organized by series and shot, identify the participating organizations and their involvements, the radiological safety precautions taken, and the recorded radiation dose levels present during the testing. The reports have been distributed to over 700 locations, including many public and college libraries and all VA regional centers throughout the U.S. and overseas. The distribution list is given at the back of each volume and is available upon request from DNA.

Third, by 1 May 1986, DNA had declassified over 1,100 publications containing information pertinent to the personnel aspects of the atmospheric nuclear tests (13). These documents are catalogued for easy reference and placed for ready availability at the National Technical Information Service in Springfield, Virginia, as explained in Appendix D.1. DNA has also declassified hundreds of relatively brief documents, such as memoranda and letters, and placed all of them at the Coordination and Information Center (CIC) in Las Vegas, Nevada. Appendix D.2 identifies CIC holdings and procedures.

Table 1. NTPR Government and contractor person years from 1978 through 1986.

	78	79	80	81	82	83	84	85	86	Total
DNA*	6	10	7	6	6	4	4	3	3	49
DOD**	63	160	197	201	186	140	60	54	60	1,121

* In-house
** In-house and Contractors

Table 2. NTPR funding in millions of dollars from 1978 through 1986.

	78	79	80	81	82	83	84	85	86	Total
DNA Contract Costs	1.91	4.75	6.91	6.66	6.31	3.03	1.60	1.94	1.75	34.86
DOD Contract Costs	3.50	6.45	9.22	8.46	7.90	4.58	3.13	2.97	2.65	48.86

The NTPR dose reconstruction program emerged from the fourth task, to provide estimates of radiation doses. This program, described in chapter 7, has been used where film badge readings were not available to determine doses for personnel in participating units and to reconstruct individual doses in specific cases, as in support of veterans claims. Part of this effort is a separate analysis of possible internal dose due to inhalation and ingestion of radioactive materials. This process was submitted for peer review to NAS. On 7 February 1986, NAS released its report, which judged the methodology to have sound scientific merit.

DNA and the NTPR teams have taken several actions to establish personal contact with as many test participants as possible, which is the fifth task identified in the preceding section. On 9 February 1978, DNA initiated its nationwide toll-free call-in program for participants to report their involvement in the atmospheric nuclear tests. The agency then issued multiple news releases that identified the purpose of the NTPR program, the toll-free number, and the DNA address. It worked in part through the U.S. Army Hometown Newscenter in Kansas City, Missouri, which had the capability to mail information to 8,066 daily and weekly newspapers, as well as 720 television and 6,394 radio stations. DNA sent letters to news directors and editors asking them to issue an enclosed press release as a service to the part of their audiences that might have participated at a nuclear test (14: 11).

The response to the initial nationwide news release was overwhelming. During the first 2 weeks after the toll-free lines were established, almost 13,000 persons called to report or inquire about their test participation. DNA progressively increased the toll-free lines from 2 to 20 (15). The calls have continued to the present, although in diminishing numbers. By 1984, DNA was averaging 150-200 calls a week and by 1985, about 65 a week (16; 17). A total of approximately 50,000 test participants have called or written to the agency* (13). The information extracted from the telephone calls and letters comprises what has come to be known as the File A data base.

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*The number for the toll-free telephone line is (800) 336-3068. In Virginia, Hawaii, and Alaska, call collect to (703) 286-5610.

DNA has also conducted three major mailings to all veterans of the nuclear tests and the Hiroshima/Nagasaki occupation for whom it had addresses (13):

- In June 1983, DNA and the Navy mailed copies of an NTPR Fact Sheet and VA Circular 10-83-61 to about 40,000 veterans. VA Circular 10-83-61 authorized treatment of test participant veterans for any ailments except those that clearly are not radiogenic in origin.
- In July 1983, DOD mailed copies of the 1983 NAS study "Multiple Myeloma among Hiroshima/Nagasaki Veterans," discussed in chapter 8, to the approximately 1,000 Hiroshima/Nagasaki veterans who had called DNA.
- In June 1985, DNA mailed to about 45,000 veterans a packet of information containing the following:
  - Results of the CDC study "Mortality and Cancer Frequency among Military Nuclear Test (SMOKY) Participants, 1957 through 1970," published in the Journal of the American Medical Association during 1983 (see chapter 8).
  - Results of the 1985 NAS mortality study, entitled Studies of Participants in Nuclear Tests (see chapter 8).
  - Results of the NTPR program
  - Information on free medical benefits available through VA
  - Request for comments on the proposed rules for responding to VA/NTPR inquiries (see chapter 3).

As the official DOD agent for the NTPR program, DNA has responded to requests for information from Congress, medical and scientific communities, veterans groups, lawyers, and citizens with special interests in NTPR. It has sent approximately 1,000 letters to the offices of U.S. Senators and Representatives, Governors, and the White House, all of which had requested information on the program (13). In addition, DNA representatives have testified at Congressional hearings from the very start of NTPR. The Director of DNA, along with other agency and DOD personnel, made statements at the hearings identified in table 3 (18).

DNA has also responded to requests for information from the media. It has provided data on NTPR to both national and local television programs and publications, including "60 Minutes," "20/20," "Good Morning, Washington," National Geographic, People magazine, and the Washington Post.

Table 3. Congressional hearings at which DNA representatives have given testimony.

Committee	Date of Testimony
• Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce --Emphasis on actions then underway in the Department of Defense to collect data on DOD personnel who participated in atmospheric nuclear weapons testing	24-26 January and 14 February 1978
• Subcommittee on the House Commmittee on Government Operations --Emphasis on DOD research to identify participants in atmospheric nuclear weapons testing and possible exposures to ionizing radiation resulting from their participation	13 July 1978
• Subcommittee on Energy, Nuclear Proliferation and Federal Services of the Senate Committee on Governmental Affairs --Emphasis on progress made by DNA and the service teams to identify participants in atmospheric nuclear weapons testing and possible exposures to ionizing radiation resulting from their participation	8 May 1979
• Senate Committee on Veterans Affairs --Emphasis on declassification of documents relevant to atmospheric nuclear weapons testing and on dose reconstruction for test participants who did not wear badges	20 June 1979
• Senate Committee on Labor and Human Resources --Emphasis on proposed Bill S. 1483, which would make the U.S. liable in incidents related to fallout from the atmospheric nuclear tests	27 October 1981
• Senate Committee on Veterans Affairs --Emphasis on status of the NTPR program and the VA adjudication process	18 April 1983

Table 3. Congressional hearings at which DNA representatives have given testimony (Continued).

Committee	Date of Testimony
● Subcommittee on Oversight and Investigations of the House Committee on Veterans' Affairs	24 May 1983
--Emphasis on the NTPR program, Operation CROSSROADS, and Stafford Warren Collection	
● Senate Committee on Veterans Affairs	11 December 1985
--Emphasis on issues resulting from a GAO report on radiation exposures received by participants in Operation CROSSROADS, conducted in 1946 at Bikini as the first postwar nuclear test series	

The sixth of the listed NTPR tasks was to identify and notify individuals whose radiation doses exceeded current Federal guidelines and to offer veterans free medical examinations at VA hospitals. Notification and medical examination programs exist for three categories of DOD test participants: Over-25-rem* Participants, Desert Rock Volunteer Observers, and Over-5-rem Participants. In addition, free VA medical examinations are available upon request to all atomic veterans. See chapter 3 for a discussion of the VA examination process.

In March 1979, the notification and veterans medical examination program was initiated for all test participants with cumulative doses from atmospheric testing in excess of 25 rem. The threshold of 25 rem was selected because it is the current recommended national guideline for a one-time, planned exposure under emergency conditions.

As of 1 May 1986, the NTPR had identified 39 DOD personnel in the Over-25-rem group, with external doses ranging from just over 25 rem to an estimated high of 98 rem. Most of these exposures resulted from a wind shift at BRAVO, detonated on 1 March 1954 at Bikini as part of Operation CASTLE (see section 4.10). Of the 37 participants who had identifiable addresses and could be contacted, 19 did and 5 did not want examinations. Twelve veterans took the examinations (13).

In May 1979, the DOD notification and VA examination program was expanded to include officer volunteer observers who took part in the Desert Rock troop exercises during the testing. These volunteers were closer to ground zero than any other participants at shot-time, and they received gamma doses ranging from a few millirem to about 14 rem. The volunteer observers at Shots NANCY (24 March 1953), BADGER (18 April 1953), SIMON (25 April 1953), and APPLE 2 (5 May 1955) were also exposed to neutron radiation (11). The first three of these shots were part of Operation UPSHOT-KNOTHOLE and are discussed in section 4.9. The fourth, Shot APPLE 2, was part of Operation TEAPOT and is discussed in section 4.11. The NTPR teams have located current addresses and succeeded in contacting 40 of the volunteer observers, as noted in chapter 2 (13).

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*See Appendix B, Glossary, for definitions of rem and other technical terms.

In June 1979, the DOD notification and VA medical examination program was expanded to include all veterans with doses over 5.0 rem in 12 consecutive months. Five rem is the current Federal guideline for allowable annual dose to radiation workers. The program now includes 1,430 personnel, about 70 percent of whom have been contacted by the NTPR teams. This is a high percentage considering the difficulty of proceeding from records 25 to 40 years old to find the current addresses. The physical examinations given by the VA to these personnel indicate a lower incidence of cancer than the national average (13).

The seventh NTPR task, sponsorship with DOE of an NAS mortality study of test participants, concluded in May 1985 with publication of Studies of Participants in Nuclear Tests. The study, conducted by the NAS National Research Council, was done on a cohort of 46,186 participants in Operations GREENHOUSE (1951), UPSHOT-KNOTHOLE (1953), CASTLE (1954), REDWING (1956), and PLUMBBOB (1957) (19). Chapter 8 discusses this effort, along with the other major followup studies of test participants.

DNA and the NTPR teams have also completed the eighth task, research on the U.S. occupation of Hiroshima and Nagasaki. DNA issued a detailed fact sheet about the occupation forces on 6 August 1980 and has since provided the document to all occupation personnel who have called or written DNA. A detailed dose reconstruction, using assumptions chosen to give an estimate of the maximum possible dose, has also been completed. The conclusion, reported in chapter 6, is that the radiation doses received by members of the occupation forces were negligible (20).

Finally, each NTPR team has assembled extensive data about each nuclear test series and shot for which it had any identified participants. The teams provide claims assistance to individuals and to the VA, which requests their help in documenting participation and determining radiation dose.

The NTPR teams have accomplished most of their original goals. As their work is completed, remaining responsibilities will be consolidated at DNA beginning in fiscal year 1987.

1.5 SUMMARY OF RADIATION DOSES.

Doses to participants at the atmospheric nuclear tests have been determined through several means. Film badge dosimetry, when available, provided a measure of the external gamma doses to persons wearing, or represented by, film badges. The primary source of recorded film badge dose data is the file maintained by Reynolds Electrical & Engineering Company, which is the official master repository of dose records for nuclear weapons tests.

Using contractor support, DNA is providing reconstructed doses that reflect the entire period of exposure, as well as exposure to neutron radiation or internal emitters, for those cases where the recorded dosimetry did not represent the full circumstances of exposure. These dose determinations, described in chapter 7, are based on specific unit activities and the actual radiological conditions. Doses so determined have correlated well with film badge readings when the circumstances of exposure are generally known.

Findings to date indicate that most external gamma doses to personnel at the tests were quite low--averaging about a half a rem. Many participants received no dose at all, and less than one percent exceeded 5 rem, the annual whole body dose limit recommended by the National Council on Radiation Protection and Measurements. Table 4, given at the end of this section, presents data provided by the NTPR teams that show the breakdown of all external gamma doses, both recorded and reconstructed.

The dose totals given in table 4 do not precisely match the estimated numbers of participants for the specific test series given in chapter 4, except for ARGUS, or the estimated total number of DOD participants in the atmospheric nuclear tests. In some cases, multiple badging of individuals led to more doses than participants; in other cases, participants had no film badge doses and reconstructed doses are pending. Moreover, the film badge

Table 4. Summary of external doses for DOD atmospheric nuclear test participants as of 1 May 1986.

Operation	Gamma Dose (rem)						
	0-0.5	0.5-1	1-3	3-5	5-10	10+	Total
TRINITY	105	15	32	10	1	1	164
CROSSROADS	32,236	4,908	2,954	14	0	0	40,112
SANDSTONE	11,706	47	25	2	2	0	11,782
RANGER	241	10	11	3	1	0	266
GREENHOUSE	2,231	954	1,612	2,419	297	18	7,531
BUSTER-JANGLE	7,412	162	190	42	4	0	7,810
TUMBLER-SNAPPER	7,807	598	247	48	9	1	8,710
IVY	8,887	350	91	6	9	10	9,353
UPSHOT-KNOTHOLE	5,442	3,671	5,173	3,044	69	15	17,414
CASTLE	5,114	1,669	4,635	833	252	149	12,652
TEAPOT	3,999	2,646	1,539	127	10	8	8,329
WIGWAM	6,766	1	2	0	0	0	6,769
REDWING	3,966	2,466	2,983	1,601	248	12	11,276
PLUMBBOB	9,866	2,157	958	82	43	7	13,113
HARDTACK I	7,242	3,611	4,614	270	76	7	15,820
ARGUS	4,500	0	0	0	0	0	4,500
HARDTACK II	1,234	118	248	23	7	1	1,631
DOMINIC I	21,591	299	467	22	20	21	22,420
DOMINIC II/ PLOWSHARE	2,155	239	173	4	1	0	2,572
TOTAL	142,500	23,921	25,954	8,550	1,049	250	202,224

dosimetry for still other participants did not cover the entire period of exposure; reconstructed doses will be required in these cases to supplement the doses already recorded. However, while the numbers in table 4 will be adjusted with further research and analysis, the overall results will not change appreciably--the preponderance of doses are expected to remain in the level below 0.5 rem.

During Operations UPSHOT-KNOTHOLE (1953), TEAPOT (1955), and PLUMBBOB (1957), all at the Nevada Test Site, about 10,000 military observers and maneuver troops were exposed to neutron radiation while observing nuclear tests from forward locations in the shot areas. Of these, 44 were volunteers positioned closer to ground zero than the other troops. Through reconstruction methods described in chapter 7, neutron doses for the volunteers were determined to be as high as 28 rem, while the highest neutron dose received by regular troops was 1.5 rem for the 500 observers at Shot TESLA, Operation TEAPOT. Neutron doses to all other troops were calculated to be less than 0.5 rem.

At some operations, the circumstances of radiation exposure were such that some participants may have ingested or inhaled radioactive materials. The internal dose from such exposures, determined through a screening methodology in most cases, resulted in a 50-year bone dose commitment of less than 0.15 rem for over 85 percent of the participants.

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2. "Statement for House of Representatives, Subcommittee on Health and the Environment." Dr. Darrell W. McIndoe, Director of the Armed Forces Radiobiology Research Institute. Bethesda, MD. 23 Jan 78. 3 p.

3. Personal Communication with Edwin T. Still, formerly Assistant to the Director (Biomedical Effects), Defense Nuclear Agency. Abby A. Johnson. McLean, VA. 13 Jun 86.

4. Memorandum for the Director, Defense Nuclear Agency, Subject: DOD Personnel Participation in Atmospheric Nuclear Weapons Testing. John P. White, Asst. Sec. of Defense, MRA&L. Wash., DC. 28 Jan 78.

5. Memorandum for the Secretaries of the Military Department; Chairman, Joint Chiefs of Staff et al.; Subject: DOD Personnel Participation in Atmospheric Nuclear Weapons Testing. John P. White, Asst. Sec. of Defense, MRA&L. Wash., DC. 28 Jan 78.

6. Memorandum for the Secretaries of the Army, Navy, and Air Force; Subject: DOD Personnel Participation in Atmospheric Nuclear Weapons Testing. R. R. Monroe, VADM, USN, Director, Defense Nuclear Agency. Wash., DC. 13 Feb 78.

7. Encls to a ltr to Paul Boren, Assistant NTPR Program Manager. William J. Brady, Technical Advisor, Environmental Sciences Dept, Reynolds Electrical & Engineering Co., Inc. Las Vegas, NV. 10 Apr 86.

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10. Interview of VADM R. R. Monroe, USN Ret. Abby A. Johnson. San Francisco, CA. 8 Jul 85.

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17. Memorandum for the Deputy, Chief of Naval Operations (Logistics), Subject: Summary Report of the Navy Nuclear Test Personnel Review (OP-455). Carl Zillig, [Dept. of the Navy] EP/S & OHD. Wash., DC. 16 Apr 85.

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SECTION 1

REFERENCE LIST (Continued)

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SECTION 2

THE WORK OF THE NTPR TEAMS

While the Defense Nuclear Agency (DNA) has been the executive agent, the Nuclear Test Personnel Review (NTPR) military service teams and a separate team at DNA's Field Command in Albuquerque, New Mexico, have been the executors of the tasks assigned the agency beginning in 1978. These five teams have expended considerable time, personnel effort, and funds meeting their responsibilities. This chapter sketches their common challenges and then traces the efforts and accomplishments of each team.

2.1 COMMON CHALLENGES.

Each NTPR team is responsible for a different constituency and has a distinctive history. At the same time, the teams have shared a number of experiences. They have all, for example, had certain problems with inadequate documentation from the testing period, although some teams have had more difficulties in this area than have the others. These problems have posed challenges to the teams in fulfilling their responsibilities, such as responding to File A personnel, meaning those individuals who called in on the toll-free DNA telephone lines or wrote to the agency concerning their participation in the atmospheric nuclear weapons tests.

2.1.1 Documentation from the Testing Period.

Inadequate documentation has been a significant problem, even though many of the source materials are detailed and useful. The sources, written 20 to 40 years ago, are housed in private, public, and Government repositories scattered across the Nation. In addition, the extant Department of Defense (DOD) records of the atmospheric test program do not emphasize personnel participation and exposure data, as Vice Admiral Robert R. Monroe explained in testimony given on 20 June 1979 before the Senate Committee on Veterans' Affairs (1):

> The reason that DOD records do not meet today's needs in this specific area derives from the views of medical science in the 1940s and 1950s concerning the hazards of ionizing radiation. Both national and international authorities at that time were more certain than they are

> today that there is negligible health risk from exposure to low-levels of ionizing radiation (e.g., a few rem). Thus the DOD-allowed exposure limits per test or series (typically 3 to 5 rem) were regarded primarily as operational safety guides, and once doses had been kept within these limits, their recording was not, in all cases, accomplished with an eye on permanency.

A major fire at the National Personnel Records Center (NPRC) in St. Louis, Missouri, compounded the difficulties. Beginning on 12 July 1973, the fire burned for 4 days. It caused at least $13.7 million in damages, and it destroyed 21.7 million records categorized as follows: 17.5 million records of Army personnel discharged between 1912 and 1959; 2,000 records of Army personnel discharged in 1973; and one million records of Air Force personnel whose last names begin with the letters I through Z and who had been discharged between 1947 and 1963. Many other records were water damaged. Only 10 to 15 percent of the 1912-1959 Army records were recovered, while about 40 percent of the Air Force records were salvaged (2: 60,31,36). The destruction of these documents created problems particularly for the Army, as is discussed in section 2.3.

2.1.2 Responses to File A Personnel.

The NTPR program has evolved into a much more extensive effort than had originally been envisioned by Congress, informed Government organizations, even by the NTPR teams. The demanding and lengthy procedure required to respond to File A personnel provides one example of this effort.

According to established guidelines, the NTPR interviewer requests the following information from each caller on the toll-free DNA telephone lines: participant's name, social security number, telephone number, date of birth, address, caller's name, caller's relationship to participant, test series, test event, test location, date of test, participant's receipt of dosimeter, participant's use of dosimeter, armed service rank, service number, unit during test, place of birth, cause of death if participant is deceased, year of death, and remarks. The responsible NTPR team proceeds with a followup letter to the caller providing information on the program. The team then conducts research to secure accurate participation and dose data, which are sent in a final letter to the caller. When the task is completed, each NTPR team will have spent about 7 years responding to its File A personnel.

The teams did not formulate any set approach to processing File A personnel at the beginning of the task. They have, however, generally used the procedures identified below. These procedures, which have evolved over time, have been followed not only for individuals who have called DNA but for all personnel on the data base, including VA cases:

- Collect information
  - --Request specified data from each caller on the DNA toll-free lines
  - --Archive records from over 100 repositories
  - --Gather data from individuals knowledgeable about the atmospheric nuclear weapons tests and personnel participation
- Establish data base to:
  - --Identify participants in an orderly fashion
  - --Incorporate relevant participation and dosimetry information from medical records, REECo files, Lexington Bluegrass Signal Depot records, as well as some 80 other sources
- Provide missing information
  - --Review assembled data for gaps
  - --Reconstruct missing data by establishing a scientifically sound and workable methodology
  - --Incorporate reconstructed information into the data base
- Develop final response
  - --Determine participation and dosimetry information for each caller on the toll-free lines
  - --Send a letter providing participation and dosimetry information to each caller.

The final File A letters are the conclusion of a lengthy procedure. The drafting and processing of these letters is a considerable effort in itself, although not so demanding as the preceding research. The Navy NTPR (NNTPR), which has drafted and sent almost 20,000 final File A letters on participation and dose, estimated the average time spent on this correspondence as follows (3):

Average File A Letter Processing Requirements

Function	Number of People	Time Per Record (min)	NTPR Work Hours Daily (for 30 Records)
Draw Records	1	3	1.5
Process Dose Data	1	10	5
Research/Draft Letter	3	45	22.5
Type Letter	1	15	7.5
Quality Control	1	10	5
Signature	1	2	1
Mail, Refile, Log	1	3	1.5
Supervision	1	8	4
	10	1 Hr. 36 Min.	48 Hrs.

The next sections summarize the work of the NTPR teams beginning with the Navy. The commentary focuses on key efforts, including responses to File A personnel, assignment of doses, notification of medical examination programs, and investigations for VA claims.

2.2 NAVY NTPR EFFORTS.

The Navy NTPR is responsible for tracking the largest group of test participants, 52 percent of the total number reported by the armed services (4). It has identified 106,942 Navy personnel, believed to be virtually all of its participants (5). In addition, the Navy claims about one-third of the approximately 50,000 File A personnel (6).

The NNTPR has had distinct advantages over the other teams in locating its personnel. Most of the Navy participants, for example, were on ships during the tests, and their exact locations could be identified through use of the ship logs and muster rolls. The NNTPR has access, too, to the fine personnel records system maintained by the Navy. Making good use of these advantages, the NNTPR has been the first team to essentially complete the tasks assigned it by DNA.

The NNTPR has concentrated on quality control in the handling and processing of data and has assembled information that will be useful for years to come. With these data, the NNTPR has prepared a number of tables, a sample of which is given below, that summarize its efforts and the participation of Navy personnel in the nuclear tests.

2.2.1 Resources.

The NNTPR office was established at the Pentagon on 21 February 1978. The Project Managers, from the beginning of the effort to the present, have been Captain Thomas H. Sherman, February to April 1978; Captain Andrew G. Nelson, May 1978 to June 1979; Captain James R. Buckley, June 1979 to April 1981; Commander R. Thomas Bell, May 1981 (Acting Project Manager); Captain William H. Loeffler, June 1981 to September 1984; and Commander R. Thomas Bell, October 1984 to present. As of 1 May 1986, the NNTPR had used 195 person years and spent $9,143,500 (7). The tables below itemize the annual expenditures (8):

NNTPR Personnel Effort--Completed and Planned
(in person years)

	FY78*	FY79	FY80	FY81	FY82
Military					
Officer	2.08	4	3.75	2.92	3
Enlisted	0.75	2.17	1.71	2.06	1.25
Civil Service	0.83	3.42	3.62	3	2
Contractor	1.67	29.67	35.07	21.11	15
TOTAL	5.33	39.26	44.15	29.09	21.25

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* FY78-FY84: Research and program development phase

NNTPR Personnel Effort--Completed and Planned (Continued)
(in person years)

	FY83	FY84*	FY85	FY86
Military				
Officer	3	3	2	2
Enlisted	1	1	1	1
Civil Service	2	2	1	1
Contractor	14	14	4	4
TOTAL	20	20	8	8

---

* FY85-on: Maintenance office phase

NNTPR Costs--Expended and Planned
(in thousand dollars)

	FY78	FY79	FY80	FY81	FY82
Separately identifiable costs (*)	205	1,524	1,748.1	1,032.7	839
Salaries and benefits (**)	71.6	173.6	177.7	191.7	220.6
TOTAL	276.6	1,697.6	1,925.8	1,224.4	1,059.6

	FY83	FY84	FY85	FY86
Separately identifiable costs (*)	953	801	300	300
Salaries and benefits (**)	208	210	150	150
TOTAL	1,161	1,011	450	450

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*Contracts, services, travel, materials, equipment rental, etc. less items in**.

**Uniformed military and civil service personnel only.

2.2.2 Results.

The NNTPR has identified and assigned external gamma doses to virtually all of the Navy test participants. The summaries in this section detail its fulfillment of assigned responsibilities.

Response to File A Personnel. As of 1 May 1986, the NNTPR had mailed nearly 20,000 File A letters with final statements on participation and radiation dose to Navy personnel who had called in on the DNA toll-free number (5). Approximately 300 additional letters will be sent as dose reconstructions are completed. The NNTPR has also mailed more than 1,500 final letters to Hiroshima/Nagasaki occupation troops and to callers who did not participate either in the occupation or the nuclear tests (9).

Assignment of Doses. The NNTPR has a recorded or a calculated radiation dose for nearly 99 percent of all Navy test participants. The team and its contractors assembled this information by searching through medical and historical records, by using film badge information, and by reconstructing doses when film badges were not available.

The NNTPR has reviewed over 99 percent of the participants' medical records (more than 105,000 records). Researchers accomplished most of this work during a 1-year period, when they examined about 1,700 records a week (6).

Doses had to be reconstructed for more than half the Navy participants since only about 45 percent of these personnel in all the test series had recorded data on exposure. The effort was even greater for Operation CROSSROADS, conducted in 1946 at Bikini as the first postwar nuclear test series. Reconstructed doses were needed for all of the approximately 37,000 Navy participants in this operation. The NNTPR spent more time determining the doses for its CROSSROADS personnel than it did for Navy participants in all the other series combined. Commander R.T. Bell, present NNTPR Project Manager, acknowledged the challenge of CROSSROADS when he referred in an interview to the "massive effort" expended by the NNTPR and its contractors on dose reconstruction (6).

Notification of Medical Examination Programs. The NNTPR has a total of 3 personnel in the Over-25-rem Program, 5 in the Volunteer Observer Program, and 503 in the Over-5-rem Program, as shown in the table below. Approximately 65 percent of those in the Over-5-rem Program participated in Shot BRAVO, which is discussed in section 4.10 as part of Operation CASTLE (1954) (5).

The NNTPR has sent notification letters to all personnel in these programs having identifiable addresses, a number totaling 464. Of this group, 150 participants stated that they wanted the medical examination provided by the Veterans Administration. Only 108, or 23 percent of the personnel notified, actually took the examination (5).

NNTPR Personnel Eligible for Medical Examination Programs (5)

1. Over-25-rem Program	Number
Total	3
Known deceased	1
Notifications sent	3
Replies received	2
Number desiring examinations	0
Number not desiring examinations	0
Number undecided or unspecified	2
Examinations administered	0
2. Volunteer Observer Program	
Total	5
Known deceased	0
Notifications sent	5
Replies received	5
Number desiring examinations	2
Number not desiring examinations	3
Examinations administered	2
3. Over-5-rem Program	
Total	503
Known deceased	58
Notifications sent	456
Replies received	243
Number desiring examinations	148
Number not desiring examinations	95
Examinations administered	106

Investigations for VA Claims. The NNTPR has provided information on participation and dose to the Veterans Administration for 1,045 claims filed for compensation benefits by Navy personnel who believe their diseases or disabilities were caused by their exposure to ionizing radiation during atmospheric nuclear weapons testing (5).

In compiling data for the VA, the NNTPR developed over 360 unit histories, usually from one to three pages, for the ships, squadrons, and staffs associated with the oceanic nuclear tests. These histories specify unit locations and activities during the test series, unit dosimetry data, and, when available, the radiological conditions present (9).

Correspondence Summary. In fulfilling its obligations, the NNTPR has processed considerable amounts of correspondence. The following table summarizes both the type and volume of correspondence for selected years (9):

NNTPR Outgoing Correspondence Totals

Type	1978	1980	1982	1984	1985	1986
Personal Inquiries	11	1,226	217	218	107	47
VA Request	14	325	132	212	223	62
Congressional	8	46	42	17	20	8
Request from Family	1	25	13	9	18	1
Request from Employer	0	12	8	2	2	0
Miscellaneous	291	58	262	227	164	30
Memorandum for the Record	33	114	58	59	16	1
FOIA	0	2	35	16	24	2
Attorney's Request	0	13	7	6	4	2
Special Medical Letters	0	586	0	0	0	0
Over-5-rem Letters	0	163	13	0	4	0
Medical Records Request	0	483	21	0	2	2
Form Letters	0	552	89	124	135	127
Final File "A" Letters	0	0	5,170	6,632	182	170
Non-Participant Letters	0	0	523	271	9	4
Total	358	3,605	6,590	7,793	910	456

2.3 ARMY NTPR EFFORTS.

The Army NTPR (ANTPR) has the second largest group of participants in the nuclear test series. It has estimated the total number of Army test participants at 50,989, of whom about 77 percent took part in CONUS and 23 percent in Pacific tests.

The ANTPR presented these figures, along with others, in its draft "History of the Army Nuclear Test Personnel Review (1978-1986)," the only such summary developed by an NTPR service team (10). Unless otherwise documented, the following sections are drawn from this 55-page text.

2.3.1 Objectives.

In 1978, the ANTPR begin pursuing its assigned tasks by researching Army documents, developing a data base, and corresponding with individual participants (11). It concentrated first on personnel identification and records retrieval for the test series involving Desert Rock troop exercises, performed at the test site to train troops in tactics for possible use on a nuclear battlefield. The series incorporating these exercises were Operation BUSTER-JANGLE (1951), Operation TUMBLER-SNAPPER (1952), Operation UPSHOT-KNOTHOLE (1953), Operation TEAPOT (1955), and Operation PLUMBBOB (1957). This particular focus was selected because of the continuing Centers for Disease Control (CDC) epidemiological investigation of Shot SMOKY, which was one of the PLUMBBOB tests, and because of Congressional requests for information. After completing this phase of the research, the ANTPR team turned its attention to Army participants in the oceanic series of nuclear tests.

ANTPR researched the available service and medical records for participants and reviewed the morning reports of Army units. The effort was challenging because of inadequate documentation of Army personnel participation:

- The 1973 fire at the St. Louis National Personnel Records Center had destroyed at least 85 percent of the Army personnel records for veterans who had left the service from 1912 to 1959.
- About 50 percent of the Army participants in the nuclear tests had taken part in Desert Rock units, which were provisional and thus did not require permanent record keeping.
- The extant records do not provide sufficient information on personnel activities and locations at the test site.

To gain the needed information, ANTPR researchers had to check virtually every morning report for every unit identified as having participated in the atmospheric nuclear weapons tests. The sheer volume of morning reports made the task time-consuming.

The ANTPR approach, like that of the other NTPR teams, evolved in response to DNA directives, along with Congressional and public needs. By August 1979, the ANTPR team had shifted its primary emphasis from research on individuals to responses to specific groups, such as the over-25-rem and over-5-rem participants, the volunteer observers, and the VA claimants. Section 2.3.3 presents statistics on these efforts.

In late 1982, the ANTPR data entry staff decreased in number, as personnel and financial resources were redirected to handle new priorities within the Army, such as the Agent Orange Task Force. At about the same time, programming and data entry errors created problems in the ANTPR computer system. In early 1983, the ANTPR Program Manager sent a memorandum to the DNA NTPR Program Manager indicating that these problems, along with the decrease in staff, had resulted in considerable curtailment of data entry within the past quarter. DNA and the Army worked together in the latter half of 1983 to identify the difficulties and prescribe solutions.

In a meeting with DNA on 31 January 1984, the Army agreed to provide funds to contract for technical support, especially to purify the ANTPR data base. The contract was awarded in September 1984, and work commenced immediately toward accomplishment of the five major ANTPR tasks, beginning with purification of the data base. Subsequent tasks involve identifying personnel and units, determining radiation exposure and entering information into the ANTPR data base, notifying test participants, and responding to requests for information from veterans, VA, and Congress. With the assistance of its contractor, the ANTPR should meet its objectives by the end of 1987.

2.3.2 Resources.

The ANTPR has had five chief administrators: Colonel Victor J. Hugo, February 1978 to September 1978; Colonel David P. Lucke, September 1978 to October 1979; Lieutenant Colonel Darwin M. Way, 17 October 1979 to June 1980; Mr. Waldemar A. Anderson, June 1980 to March 1981; and Mr. Richard S. Christian, March 1981 to present.

As of 1 May 1986, the ANTPR had used 234 person years and spent over $5,700,000. The tables below itemize these expenditures on an annual basis. As shown in the table on costs, the expenditures for such items as contracts, services, and equipment increased in fiscal year 1984, when the ANTPR engaged a contractor to purify its data base and provide other technical support (12).

ANTPR Personnel Effort--Completed and Planned
(in person years)

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
10	41	41	37	37	33	3	16	16

ANTPR Costs--Expended and Planned
(in thousands of dollars)

	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
1. Separately identifiable costs (contracts, services, travel, materials, equipment rental, etc.) but not including those in item 2 below.	23	25	36	40	160	110	720	730	760
2. Salaries and benefits for uniformed military and Civil Service personnel.	168	448	552	507	558	523	66	150	156

2.3.3 Results.

As work continues on accomplishment of the primary ANTPR tasks, the statistics for the ANTPR programs will change. The numbers given below were current as of 1 May 1986.

Response to File A Personnel. The NTPR call-in program has elicited responses from 14,340 Army participants. This number comprises approximately 30 percent of the total group that has telephoned on the DNA toll-free line or written to the agency (12). The ANTPR will send final letters to these participants when work is completed on dose identification and reconstruction.

Notification of Medical Examination Programs. Among the NTPR teams, ANTPR has the largest number of individuals, a total of 24, in the Volunteer Observer Program. The table below shows statistics of this program, as well as the Over-25-rem and Over-5-rem Programs (12). The ANTPR has notified all personnel in these programs who have identifiable addresses.

ANTPR Personnel Eligible for
Medical Examination Programs

		Number
1.	Over-25-rem-Program	
	Total	4
	Known deceased	1
	Notifications sent	4
	Replies received	2
	Number desiring examinations	1
	Number not desiring examinations	1
	Examinations administered	1
2.	Volunteer Observer Program	
	Total	24
	Known deceased	2
	Notifications sent	24
	Replies received	11
	Number desiring examinations	5
	Number not desiring examinations	6
	Examinations administered	1
3.	Over-5-rem-Program	
	Total	389
	Known deceased	38
	Notifications sent	178
	Replies received	95
	Number desiring examinations	58
	Number not desiring examinations	37
	Examinations administered	58

Investigations for VA Claims. The ANTPR has provided participation, unit histories, and dose data for 812 VA claims filed by Army veterans for compensation benefits from the VA (12). ANTPR spends more time per VA claim than the other NTPR teams because of the inadequate documentation of Army personnel participation, discussed earlier. To provide VA with the necessary information, ANTPR researchers must scrutinize individual unit morning reports and secondary sources to verify claimants' participation in the nuclear tests.

2.4 AIR FORCE NTPR EFFORTS.

The Air Force NTPR (AFNTPR) team is responsible for about 25,000 participants, which is approximately 12 percent of the total number of U.S. nuclear test participants. It was tasked with assembling participant and dose information for its personnel in those series postdating 1947, when the Air Force was established as a separate military service. The Army Air Force personnel who took part in the two preceding operations, TRINITY (1945) and CROSSROADS (1946), are the responsibility of the ANTPR. The exception involves Army Air Force participants who later entered the Air Force and took part in subsequent nuclear test series. DNA assigned responsibility to AFNTPR for compiling Army and Air Force records on these personnel in response to claims filed with the Veterans Administration (13).

2.4.1 Resources.

The AFNTPR Team Chief, part of the Air Force Surgeon General's office, oversees the effort, which is conducted at the Air Force Occupational and Environmental Health Laboratory (OEHL), Brooks Air Force Base (AFB). OEHL has a radiation services division and is a logical organization for involvement.

AFNTPR was officially established in March 1979. During 1978, when a basis was being laid for the AFNTPR, Lieutenant Colonel George S. Kush, USAF, attended NTPR meetings. The first AFNTPR Team Chief was Colonel Paul F. Fallon, who held the position from March 1979 to February 1984. His successor is Colonel William D. Gibbons, February 1984 to the present. The following Project Officers have managed the AFNTPR office at OEHL: Captain John L. Ricci, September 1978 to September 1979; Captain Robert J. Berger, September 1979 to May 1981; Captain David S. Pitts, May 1981 to June 1985; Mr. John A. Herman, June 1985 to January 1986; and Mr. William D. Holland, January 1986 to present.

As of 1 May 1986, the Team Chiefs and Project Officers had overseen a total AFNTPR expenditure of 175 person years and $3,924,000 (14). The numbers were largest in the early 1980s, as with the other service teams. The following tables indicate the annual expenditures (14; 15):

AFNTPR Personnel Effort--Completed and Planned
(in person years)*

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
0.18	7.65	33.7	44.30	38.30	25.5	16.0	7.0	2.0

*Does not include Air Staff time.

AFNTPR Costs--Expended and Planned
(in thousands of dollars)*

	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
1. Separately identifiable costs(contracts, services, travel, materials, equip. rental, etc.) but not including those in item 2 below.	1.5	148	525	722	590	486	7	2.5	1.50
2. Salaries and benefits for uniformed military and civil service personnel.*	4.1	100	187	285	315	231	236	58	24
TOTAL	5.6	248	712	1007	905	717	243	60.5	25.5

*Does not include salaries for Air Staff.

2.4.2 Results.

The AFNTPR has successfully completed most of its tasks. Team Project Officers attribute much of the success to a solid research effort, conducted at such sites as Brooks AFB, Kirtland AFB, Maxwell AFB, Randolph AFB, Scott AFB, Tinker AFB, Los Alamos National Laboratories, and Reynolds Electrical & Engineering Company of Las Vegas (13).

Response to File A Personnel. The AFNTPR has essentially finished its File A effort, meaning its letters to participants who called DNA on the toll-free number. The team has completed 8,047 File A cases, which comprises 100 percent of the currently known Air Force cases. Should DNA forward any additional cases, AFNTPR is prepared to conduct the necessary research (14).

The AFNTPR has been responsible for a lesser number of File A personnel than have the NNTPR and the ANTPR. The task for the AFNTPR has been compounded, however, because many Air Force participants attended more than one series and thus required comparatively more research.

Assignment of Doses. The compilation of dose information for Air Force test participants is also nearing completion. As of 1 May 1986, the AFNTPR had identified 23,403 of the estimated total participants (14). This data base will become an integral part of the Air Force Master Radiation History Repository at OEHL.

Notification of Medical Examination Programs. The Air Force has 32 participants in the Over-25-rem Program, which is the largest number of participants for this program among the NTPR teams. Twenty five of the Air Force participants were stationed on Rongerik Island and took part in Shot BRAVO of the 1954 Operation CASTLE (see section 4.10).

Cloud-sampling pilots and crews often received higher doses than did other test participants because their missions required them to fly near and through the clouds resulting from the nuclear detonations. The cloud-sampling teams were commonly authorized special exposure limits so they could accomplish their assigned tasks. As noted in chapter 4, these limits ranged from 3.9 rem at such series as BUSTER-JANGLE, TUMBLER-SNAPPER, IVY, UPSHOT-KNOTHOLE, and TEAPOT, among others, to 10 rem at Operation HARDTACK II and 20 rem at Operation DOMINIC I.

The next table presents statistics on the Over-25-rem Program, the Volunteer Observer Program, and the Over-5-rem Program. The AFNTPR has notified all personnel in these categories that have identifiable addresses (14).

AFNTPR Personnel Eligible for
Medical Examination Programs

	Number
1. Over-25-rem-Program	
Total	32
Known deceased	2
Notifications sent	30
Replies received	22
Number desiring examinations	18
Number not desiring examinations	4
Examinations administered	11
2. Volunteer Observer Program	
Total	6
Known deceased	1
Notifications sent	5
Replies received	3
Number desiring examinations	0
Number not desiring examinations	3
Examinations administered	0
3. Over-5-rem-Program	
Total	508
Known deceased	61
Notifications sent	334
Replies received	185
Number desiring examinations	138
Number not desiring examinations	47
Examinations administered	53

Investigations for VA and Department of Labor Claims. The AFNTPR has provided participation and dose information to the Veterans Administration for 266 VA claims filed by Air Force test participants (14). It had given the same kinds of data to the Department of Labor (DOL) for the one DOL claim filed by a civilian working under contract to the Air Force during nuclear testing (16).

2.5 MARINE CORPS NTPR EFFORTS.

The Marine Corps NTPR (MCNTPR) is responsible for an estimated 11,500 participants in the atmospheric nuclear weapons tests. To provide participation and dose information for these personnel, the MCNTPR developed and continues to pursue a vigorous outreach program, which is one of the most distinctive characteristics of its efforts. The MCNTPR has completed most of its assigned tasks, as noted below.

2.5.1 Resources.

From its inception in early 1978 to the present, the MCNTPR has engaged a total of 26 Marine Corps personnel, including four Project Coordinators: Major Rafael Negron, January 1978 to April 1979; Captain James W. McNabb, May 1979 to June 1982; Major Michael J. Shinabeck, July 1982 to May 1983; and Major Daniel G. Martinez, May 1983 to present.

As of 1 May 1986, the MCNTPR effort had cost a total of 39 person years and $832,000. The largest expenditures were during 1980-82, as shown in the following tables (17; 18):

MCNTPR Effort--Completed and Planned
(in person years)

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY 86
1.5	4.8	6.8	6.5	6.5	4.0	3.0	3.0	3.0

MCNTPR Costs--Expended and Planned
(in thousands of dollars)

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
22	77	168	160	160	70	50	60	65

The dollar costs are for salaries and benefits. Specific data are not available for contracts, services, travel, materials, and equipment rental during FY78 through FY85, although the expenditures were minimal. The cost for equipment procurement has been negligible since the MCNTPR's inception.

2.5.2 Results.

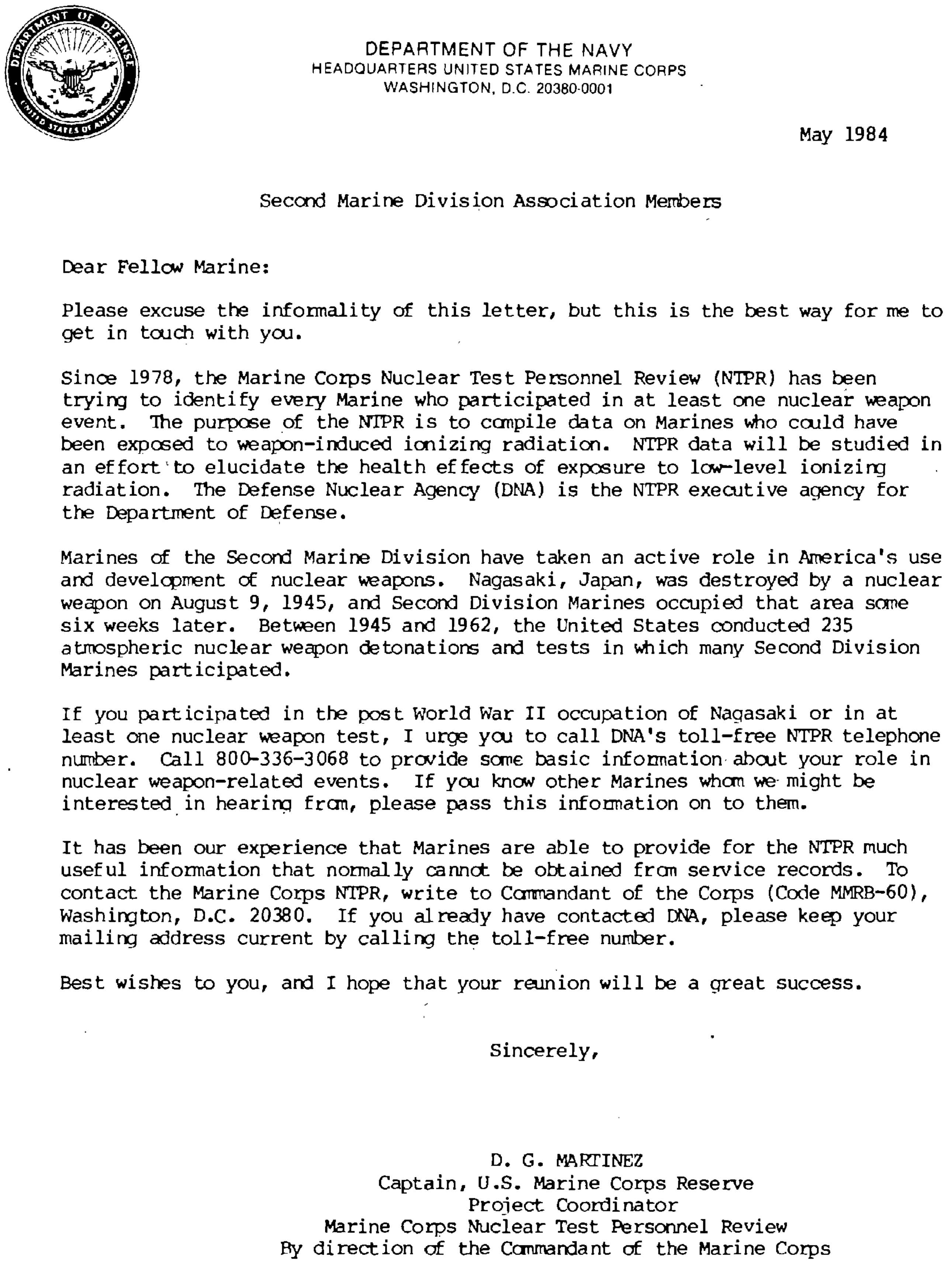
The personnel effort and dollar costs have brought some "positive results," to quote Major Daniel Martinez, the present MCNTPR Project Coordinator (19). This section discusses accomplishments beginning with the Outreach Program, which includes commentary on the MCNTPR response to File A personnel.

Outreach Program. One of the specific NTPR tasks, as noted in the latest as well as all previous NTPR Fact Sheets, is to "establish personal contact with as many test participants as possible" (20). Both the NNTPR and the MCNTPR developed active outreach programs, with the MCNTPR making this effort its highest priority in 1985 and 1986. The emphasis resulted in a considerable amount of additional information from participants who had not yet contacted DNA.

As of 1 May 1986, the MCNTPR had sent letters with information on participation and radiation dose to 3,600 of the 4,500 Marine Corps personnel who used the toll-free DNA telephone number or wrote to the Agency. The correspondence went to all participants having identifiable addresses. Because addresses had changed and return addresses had not been given, 325 of the letters were returned (21).

The MCNTPR has used and continues to use several strategies to locate additional personnel. One of the first involved a computer comparison check between known participants in the nuclear tests and retired Marines. Personnel who had not yet contacted DNA were sent questionnaires filled in with available information. They were asked to check the incorporated data, complete, and then return the forms in the stamped and addressed envelopes that had been enclosed (22). The last of these questionnaires were mailed in August 1985.

The MCNTPR has had good success with advertisements in periodicals, such as Leatherneck Magazine and the Marine Corps Gazette, and letters to Marine Corps associations celebrating reunions. Among the groups recently contacted are the 1st, 2nd, 3rd, 4th, 5th, and 6th Marine Division Associations; the Marine Corps League; and the Woman Marines Association. The MCNTPR sent 3,000 copies of the circular shown in figure 2 to the 2nd Marine Division. This circular alone drew 500 responses (22). Through the Outreach Program, the MCNTPR team has, to quote from the letter sent to the 2nd Marine Division Association, collected "useful information that normally cannot be obtained from service records."



DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380-0001

May 1984

Second Marine Division Association Members

Dear Fellow Marine:

Please excuse the informality of this letter, but this is the best way for me to get in touch with you.

Since 1978, the Marine Corps Nuclear Test Personnel Review (NTPR) has been trying to identify every Marine who participated in at least one nuclear weapon event. The purpose of the NTPR is to compile data on Marines who could have been exposed to weapon-induced ionizing radiation. NTPR data will be studied in an effort to elucidate the health effects of exposure to low-level ionizing radiation. The Defense Nuclear Agency (DNA) is the NTPR executive agency for the Department of Defense.

Marines of the Second Marine Division have taken an active role in America's use and development of nuclear weapons. Nagasaki, Japan, was destroyed by a nuclear weapon on August 9, 1945, and Second Division Marines occupied that area some six weeks later. Between 1945 and 1962, the United States conducted 235 atmospheric nuclear weapon detonations and tests in which many Second Division Marines participated.

If you participated in the post World War II occupation of Nagasaki or in at least one nuclear weapon test, I urge you to call DNA's toll-free NTPR telephone number. Call 800-336-3068 to provide some basic information about your role in nuclear weapon-related events. If you know other Marines whom we might be interested in hearing from, please pass this information on to them.

It has been our experience that Marines are able to provide for the NTPR much useful information that normally cannot be obtained from service records. To contact the Marine Corps NTPR, write to Commandant of the Corps (Code MMRB-60), Washington, D.C. 20380. If you already have contacted DNA, please keep your mailing address current by calling the toll-free number.

Best wishes to you, and I hope that your reunion will be a great success.

Sincerely,

D. G. MARTINEZ
Captain, U.S. Marine Corps Reserve
Project Coordinator
Marine Corps Nuclear Test Personnel Review
By direction of the Commandant of the Marine Corps

Figure 2. Letter sent to the Second Marine Division Association as part of the MCNTPR Outreach Program.

Assignment of Doses. The MCNTPR has verified the participation of 11,046 of the estimated 11,100 Marine Corps test participants. It has dose information for 10,788, or approximately 98 percent, of these participants (21). Radiation doses for the remaining participants are being determined according to the procedures identified in chapter 7.

Notification of Medical Examination Programs. The MCNTPR and the Field Command NTPR (see section 2.6) are the only NTPR teams having no personnel in the Over-25-rem Program. Six Marine Corps personnel are in the Volunteer Observer Program and 29 in the Over-5-rem Program, as shown in the next table. The MCNTPR has notified all of the participants, a total of 27, who have identifiable addresses (21).

MCNTPR Personnel Eligible for Medical Examination Programs

		Number
1.	Volunteer Observer Program	
	Total	6
	Known deceased	0
	Notifications sent	6
	Replies received	6
	Number desiring examinations	4
	Number not desiring examinations	1
	Number undecided or unspecified	1
	Examinations administered	3
2.	Over-5-rem Program	
	Total	29
	Known deceased	3
	Notifications sent	21
	Replies received	13
	Number desiring examinations	11
	Number not desiring examinations	1
	Number undecided or unspecified	1
	Examinations administered	4

Investigations for VA Claims. The MCNTPR has provided participation and dose information for 179 VA claims filed by Marine Corps personnel (21).

2.6 FIELD COMMAND NTPR EFFORTS.

Among the NTPR teams, the Field Command NTPR (FCNTPR) is responsible for the group of nuclear test participants most difficult to track and quantify. DNA tasked the FCNTPR with providing information about and to nonmilitary DOD participants categorized as follows: civilians from the Secretary of Defense level and their contractors, civilians and their contractors from agencies other than DOD and DOE, and invited U.S. and foreign observers of the nuclear tests. The FCNTPR has identified about 6,000 participants in the given groups and will assume responsibility for the remaining personnel who cannot be identified with one of the services (23).

2.6.1 FCNTPR Tasking.

On 1 May 1951, the organization that today is Field Command was established as part of the Armed Forces Special Weapons Project (AFSWP). AFSWP was redesignated the Defense Atomic Support Agency in 1959 and then the Defense Nuclear Agency in 1971. On 7 June 1978, DNA sent a tasking letter to Field Command DNA requiring it to function generally "in the same manner as the four military services to provide an input to the NTPR covering the personnel of AFSWP, and their contractors and laboratories for all atmospheric tests" (24).

William S. Isengard, the first FCNTPR Project Officer, noted that FCNTPR was starting "several months downstream" of the other NTPR teams and that the delay was both bad and good. The disadvantage was that FCNTPR would have "less time" for research on Shot SMOKY and the other nuclear tests. The advantage was that FCNTPR could learn from the experience of the other teams (24).

2.6.2 Resources.

Field Command recognized the challenge of the NTPR tasking and acknowledged that "some of our best people," those "capable of working independently with a minimum of day-to-day supervision," would be required. The personnel needed would include at least two researchers and a computer systems analyst/ programmer (24). Beginning in 1979 and continuing to the present, the FCNTPR team has usually consisted of three persons, military and civilian. The following Project Officers have coordinated the team: Mr. William S. Isengard, 1978; Major James E. Thomas and Major David E. Hansen, 1979; Captain Mark L.

Davis, 1980 to August 1982; Major Joe A. Stinson, August 1982 to present. As of 1 May 1986, the FCNTPR effort had cost 24 person years and $240,000 (25; 26). The annual FCNTPR budget, excluding military pay, has been about $29,000 and has included salaries and benefits for civilian personnel, transportation, equipment, supplies and materials, and contracted services (23).

2.6.3 Results.

Compared to the other NTPR teams, FCNTPR has had a greater challenge identifying its personnel, their participation, and their doses. The FCNTPR has lacked good source documents. Unlike their counterparts on the other teams, FCNTPR researchers have not been able to use ship logs, morning reports, or the records generated by military retirement pay centers. Moreover, they have experienced difficulties finding information on certain DOD contracting organizations, many of which no longer exist. To assist research on these organizations, Major Stinson has developed and published a reference book listing the contracting organizations that have been identified (27).

Response to File A Personnel. The FCNTPR has contacted over 500 participants who used the DNA toll-free lines. Many of these participants have, however, been transferred to the other NTPR teams. As of 1 May 1986, the FCNTPR File A consisted of 297 participants. The team has sent final letters on participation and dose to 119 of these personnel. The status of the remaining 178 participants is as follows (25; 26):

- Dose reconstructions are required for 34 personnel.
- FCNTPR is awaiting information from 14 personnel concerning their test participation.
- FCNTPR cannot locate current addresses or does not have sufficient data to determine test participation for 130 participants.

FCNTPR researchers also have identified approximately 500 Canadian observers of the Continental United States (CONUS) tests and believe there may have been as many as 500 more. FCNTPR has received permission from DNA to contact the Canadian Government concerning these personnel (23).

Notification of Medical Examination Programs. The FCNTPR has dose information, primarily from film badges, for almost all of its personnel. Unlike the other NTPR teams, it has no participants in the Over-25-rem Program or the Volunteer Observer Program. The team has only one participant in the Over-5-rem Program. Researchers have not succeeded in finding a current address for this individual (23).

Investigations for Department of Labor Claims. None of the Field Command personnel has filed a claim with the Department of Labor (23).

SECTION 2

REFERENCE LIST

1. Veterans' Claims for Disabilities from Nuclear Weapons Testing. US Congress, Senate, Committee on Veterans' Affairs. 96th Cong., 1st sess. Jun 79. p. 126.

2. "Protecting Federal Records Centers and Archives from Fire." General Services Administration. Wash., DC.: GPO. #022-002-00049-0. Apr 77. 202 p.

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5. Memorandum for the Director, Biomedical Effects, DNA, Subject: Navy NTPR Report. CDR R.T. Bell, USN. Navy NTPR. Wash., DC. 20 May 1986.

6. Interview of CDR R.T. Bell, USN, and LCDR M.P. Grisson, USN. Abby A. Johnson. Wash., DC. 2 May 85.

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SECTION 3

THE NTPR PROGRAM, THE DEPARTMENT OF ENERGY, AND THE VETERANS ADMINISTRATION

The Department of Energy (DOE) and the Veterans Administration (VA) do not have separate Nuclear Test Personnel Review (NTPR) teams or organizations. They interact, nonetheless, in significant ways with the NTPR program. Their efforts, particularly with the information made available by DOE and the health services provided by the VA, have been developed to address present and future needs of concerned veterans and other interested parties.

3.1 INTERACTIONS BETWEEN THE DEPARTMENT OF ENERGY AND THE NTPR PROGRAM.

With its contractors, the Department of Energy has substantially advanced the NTPR program. One contractor, Reynolds Electrical & Engineering Company (REECo) of Las Vegas, Nevada, maintains the official master file of dose records for the atmospheric nuclear weapons testing program. It also has key responsibilities for the Coordination and Information Center (CIC). A public archives housed in Las Vegas, CIC contains unclassified historical documentation relevant to atmospheric nuclear weapons testing.

3.1.1 The Master File of Dose Records.

REECo was a prime support contractor of the DOE (originally the Atomic Energy Commission--AEC) throughout most of the atmospheric nuclear weapons testing and has been a company of EG&G, Inc., since 1967. It has been permitted to support the Department of Defense (DOD) and the military services through agreements between DOE and DOD (1).

Started in 1923, REECo was selected to construct electrical facilities at Los Alamos, New Mexico, for the 16 July 1945 detonation of Project TRINITY. The company began construction at the Nevada testing site, identified in chapter 4, for the AEC in December 1950. In December 1952, it signed a support contract with the AEC that included the operation of all facilities at the test site except for feeding, housing, and camp services; maintenance of

Government property and equipment; and labor and service assistance to the AEC and scientific parties (1).

Additional functions were incorporated into the contract during subsequent years. In July 1955, the company assumed responsibility from the military for "radiological safety services" at the test site. It maintained this responsibility throughout the remaining period of atmospheric nuclear weapons testing (1).

As early as 1957, REECo began receiving requests for dosimetry information and collecting all records indicating personnel exposures to ionizing radiation during the atmospheric nuclear tests. This quickly developed into a major effort, resulting in a substantial number of records concerning individual film badge issues, cumulations of badges for an individual for a given series, contemporaneous summations of the badge data, some of the badges themselves, and a collection of other documents pertinent to personnel dosimetry.

In 1966, REECo received funding from DNA to automate the assembled information on radiation doses. From 1967 to 1969, five keypunch operators transferred approximately 400,000 records to 80-column punched cards, organized by continental and oceanic testing and according to year. Of these records, more than 232,000 were for the atmospheric testing period 1945 through 1962. By 1971, the records had been placed on rolls of 35-millimeter microfilm, and by 1974 on 16-millimeter microfilm cassettes and microfiche. In addition, REECo microfilmed 400 boxes of source documents for the dosimetry records. These documents, like the dose records, were organized chronologically, according to continental and oceanic test series, and were placed on 16-millimeter microfilm cassettes. In 1978, DOE and DNA began funding REECo for a dosimetry project to establish a data base of all atmospheric nuclear testing records. The data base now comprises about 1.6 million records, including underground testing records. Of these, approximately 387,000 are dose records for DOD and AEC participants in atmospheric nuclear testing (2).

To check the accuracy of the dose data, incorporate additional data into the file, and ensure that the information is representative of DOD participants, the NTPR program conducted:

- Research into the historical documentation of numerous individual shots and test series
- A reliability check of radiation dose records obtained from 7,900 medical records of Navy personnel
- Dose reconstructions for participants in several shots and series, including Shot SMOKY of the 1957 Operation PLUMBBOB
- Spot checks of film badge readings for members of units that maneuvered in proximity to each other and thus should have received comparable exposures.

These efforts, among others, showed dose results similar to the REECo averages of about half a rem for nearly all participants. Less than one percent of the doses exceeded the current allowable annual Federal standard (3).

The NTPR program has been supported from its beginnings by the REECo dose data. In 1978, at the start of their work, the NTPR teams had access to a useful file of dosimetry information. Then, as now, REECo has provided dose data and accompanying source documents on request to DNA, the NTPR teams, the VA, other organizations, and individuals upon request. The DOE managers of the dosimetry research project have been John D. Moroney, 1978-1980, and Michael A. Marelli, 1980 to the present. REECo's efforts have been directed primarily by W. Jay Brady.

3.1.2 The Coordination and Information Center.

In March 1979, the Department of Energy established the Coordination and Information Center, which is the Government's public archives for all unclassified documents relating to atmospheric nuclear weapons testing. Administered by the DOE Nevada Operations Office (DOE/NVOO), Las Vegas, CIC is operated by REECo (4).

CIC, which initiated document acquisition in the fall of 1979, houses an estimated 125,000 documents pertinent to U.S. nuclear weapons testing and NTPR. Collection activities are continuing, and it is anticipated that CIC will ultimately contain about 200,000 documents. Some of these sources were formerly classified, but all are now unclassified (4).

DOE/NVOO is responsible for data collection. One of its contractors, History Associates Incorporated (HAI), is collecting pertinent information under the direction of the Historian's Office, DOE Headquarters. The effort initially focused on sources concerned with offsite radioactive fallout from U.S. nuclear weapons testing. It was later broadened to include documents relevant to onsite as well as offsite fallout, oceanic as well as continental nuclear testing, and military as well as civilian participation in the tests (5).

HAI has reviewed and sent to CIC selections from some major collections, including materials from DOE Headquarters and the Los Alamos National Laboratory (LANL). The collection at DOE Headquarters provided minutes from meetings of the AEC, the General Advisory Committee established by AEC to advise on the testing, and the AEC/Military Liaison Committee, as well as staff papers and records of the Division of Military Application and the Division of Biology and Medicine. The LANL archives made documents available concerning the Test Organization, which was responsible for conducting a number of the nuclear test series; scientific studies performed as part of the tests; and fallout resulting from the detonations. In addition, some significant collections were located at such sites as the Navy Bureau of Ships, the Naval Radiological Defense Laboratory, and the Oak Ridge Center for Atomic Research (5).

The DOE/NVOO Coordination and Information Center is a valuable public resource on atmospheric nuclear weapons testing. A substantial number of the documents have been selected by professional historians according to established screening criteria, some of which are highlighted in figure 3. These researchers have identified the materials by location, collection, and folder title. Such identifiers make it possible to trace the documentation to its original source (5; 6).

Appendix D.2 provides further information on the scope of the CIC collection and on facility policies and procedures.

DOE SCREENING CRITERIA FOR DOCUMENT COLLECTION

GENERAL CRITERIA

All pertinent policy, program, correspondence, and public relations documents of the Atomic Energy Commission and other Government agencies and organizations relating to 1) radiological fallout onsite and offsite from atmospheric and underground nuclear testing between 1945 and 1972 and the technology of predicting and measuring that fallout; 2) the biological and environmental effects of radiation; 3) the organizational structure and responsibilities, planning, and conduct of nuclear testing; 4) the development of radiation safety standards, and 5) safety issues and operations in nuclear testing.

SELECTED SPECIFIC CRITERIA

- All pertinent documents relating to specific military or civilian personnel at the Nevada or Pacific Test Sites, including units, locations, assignments during atmospheric testing, any radiation dosage received, organization responsibilities, job position descriptions, delegations of authority, and test series histories as they relate to test organization.
- All pertinent documents relating to both on-site and off-site fallout, including atmospheric nuclear test exposure or dose predictions, exposure/dose data, and monitoring policy, technology, instrumentation, training, personnel and field team notes.
- All pertinent documents relating to atmospheric nuclear test safety, the development of radiation safety standards, and reports of and requirements for decontamination and evacuation either offsite or onsite.
- All pertinent "after action" reports concerning atmospheric nuclear tests.
- All aerial and ground monitoring records, including air sampling, air crew, or cloud tracking.
- All pertinent documents relating to cleanup activities, including efforts to decontaminate tracking aircraft and ships.

Figure 3. Selected DOE screening criteria for CIC document collection.

3.2 COOPERATION BETWEEN THE VETERANS ADMINISTRATION AND THE NTPR PROGRAM.

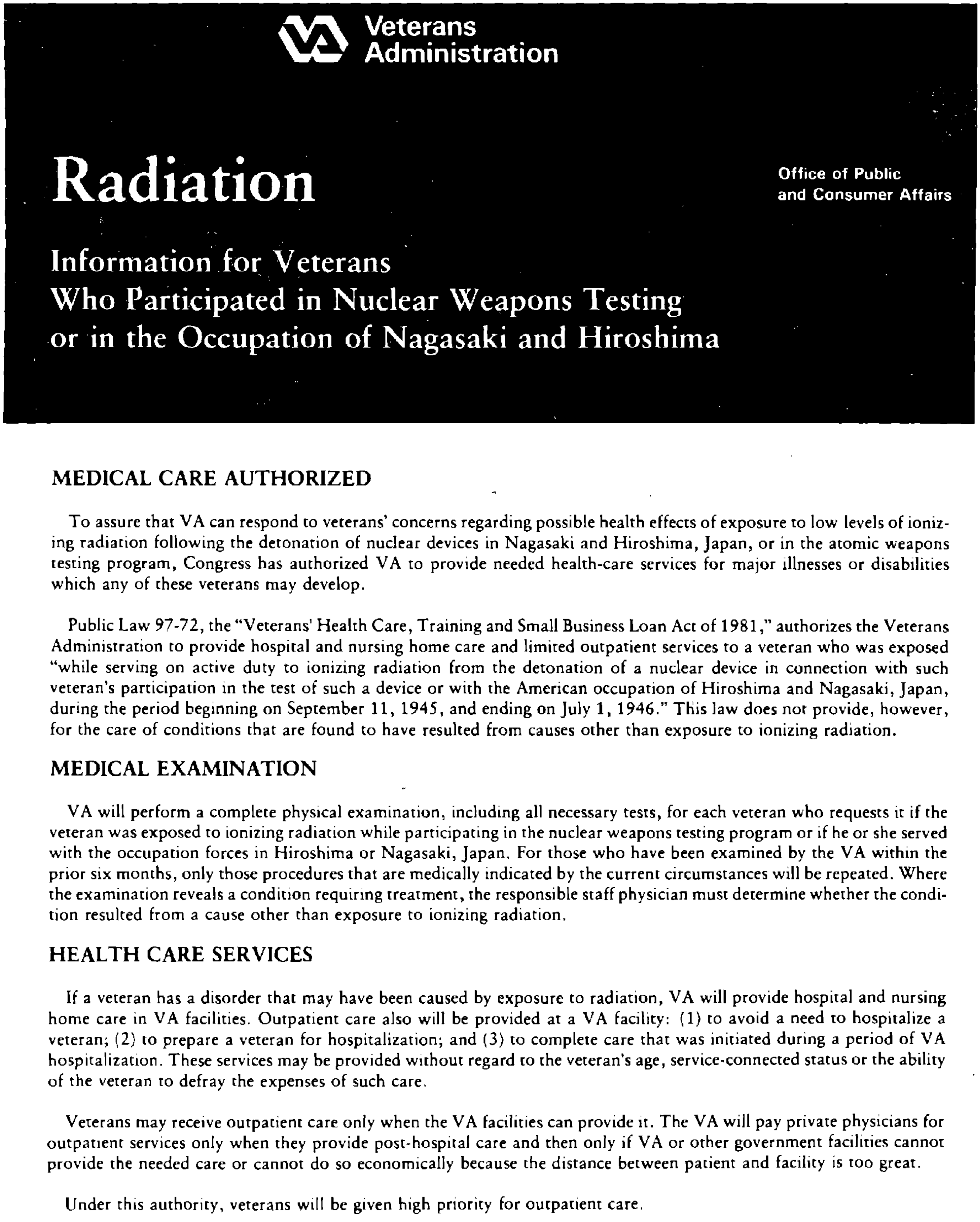
On 15 June 1979, Vice Admiral Robert Monroe and Dorothy L. Starbuck, Chief Benefits Director at VA, signed a Memorandum of Understanding on behalf of the Department of Defense and the Veterans Administration. The understanding was "to formalize and improve existing procedures to ensure the most complete investigation of veterans' ionizing radiation claims." DOD and VA representatives had cooperated closely regarding these claims during the preceding year but thought they were "in a position to do more, particularly in cases for which no recorded radiation dosage is available." As stated in the document, VA would "determine the critical elements of information necessary to support each case" and DOD would "thoroughly research each case to develop as much as possible the information needed" (7). This general procedure has remained intact. Through its Service teams, the NTPR program gives the VA information useful in providing medical care and compensation to eligible veterans (8).

3.2.1 VA Medical Examinations and Health Care Services.

The VA Office of Public and Consumer Affairs distributes a flier identifying the medical care available to eligible veterans of the atmospheric nuclear testing and the Hiroshima and Nagasaki occupation. This section highlights and extends the information presented in the flier, reproduced as figure 4.

Medical Examinations. As it has throughout the NTPR effort, the VA will give a complete physical examination, including all requisite tests, upon request to any veteran exposed to ionizing radiation during the nuclear tests or the Hiroshima and Nagasaki occupation. The NTPR teams, as indicated in chapter 2, send special notifications concerning the availability of these examinations to personnel whose radiation doses exceeded current Federal guidelines: Over-25-rem Participants, Desert Rock Volunteer Observers, and Over-5-rem Participants.

Health Care Services. The "Veterans' Health Care, Training, and Small Business Loan Act of 1981," enacted on 3 November 1981 as Public Law 97-72, authorized the VA to provide hospital and nursing home care and limited



Veterans Administration

Radiation

Office of Public and Consumer Affairs

Information for Veterans Who Participated in Nuclear Weapons Testing or in the Occupation of Nagasaki and Hiroshima

MEDICAL CARE AUTHORIZED

To assure that VA can respond to veterans' concerns regarding possible health effects of exposure to low levels of ionizing radiation following the detonation of nuclear devices in Nagasaki and Hiroshima, Japan, or in the atomic weapons testing program, Congress has authorized VA to provide needed health-care services for major illnesses or disabilities which any of these veterans may develop.

Public Law 97-72, the "Veterans' Health Care, Training and Small Business Loan Act of 1981," authorizes the Veterans Administration to provide hospital and nursing home care and limited outpatient services to a veteran who was exposed "while serving on active duty to ionizing radiation from the detonation of a nuclear device in connection with such veteran's participation in the test of such a device or with the American occupation of Hiroshima and Nagasaki, Japan, during the period beginning on September 11, 1945, and ending on July 1, 1946." This law does not provide, however, for the care of conditions that are found to have resulted from causes other than exposure to ionizing radiation.

MEDICAL EXAMINATION

VA will perform a complete physical examination, including all necessary tests, for each veteran who requests it if the veteran was exposed to ionizing radiation while participating in the nuclear weapons testing program or if he or she served with the occupation forces in Hiroshima or Nagasaki, Japan. For those who have been examined by the VA within the prior six months, only those procedures that are medically indicated by the current circumstances will be repeated. Where the examination reveals a condition requiring treatment, the responsible staff physician must determine whether the condition resulted from a cause other than exposure to ionizing radiation.

HEALTH CARE SERVICES

If a veteran has a disorder that may have been caused by exposure to radiation, VA will provide hospital and nursing home care in VA facilities. Outpatient care also will be provided at a VA facility: (1) to avoid a need to hospitalize a veteran; (2) to prepare a veteran for hospitalization; and (3) to complete care that was initiated during a period of VA hospitalization. These services may be provided without regard to the veteran's age, service-connected status or the ability of the veteran to defray the expenses of such care.

Veterans may receive outpatient care only when the VA facilities can provide it. The VA will pay private physicians for outpatient services only when they provide post-hospital care and then only if VA or other government facilities cannot provide the needed care or cannot do so economically because the distance between patient and facility is too great.

Under this authority, veterans will be given high priority for outpatient care.

Figure 4. VA medical care available to eligible veterans of U.S. atmospheric nuclear testing and the occupation of Hiroshima and Nagasaki, Japan.

HEALTH CARE EXCEPTIONS

Health care services may not be provided under the law for conditions that are found, after medical examination, to have resulted from a cause other than exposure to radiation. The following types of conditions are ordinarily considered to be due to a cause other than exposure to low-level ionizing radiation.

a. Congenital or developmental conditions (conditions the veteran was born with or that are hereditary);

b. Conditions that the veteran had before military service;

c. Conditions resulting from an injury;

d. Conditions having a specific and well-established cause, e.g., tuberculosis, gout; and

e. Common, well-understood conditions, such as inguinal hernia and acute appendicitis.

If the examining physician believes that a veteran requires care for any of these conditions and presents a complicating circumstance that makes the provision of care under this authority appropriate, he or she may decide to provide it after consulting with the facility chief of staff and the environmental physician.

CLAIMS FOR COMPENSATION BENEFITS

Public Law 97-72 provides for health care only. If a veteran is found to be eligible for care under this law, the decision does not mean that the disability is service-connected, nor does it in any way affecr determinations regarding entitlement for compensation. Claims for compensation for disabilities the veteran believes are due to exposure to radiation should be filed with the VA regional office.

Individual veterans should contact the nearest VA medical center to determine their eligibility for health care. If the veteran possesses any military records, they should be brought to the medical center in order to speed the process of determining eligibility and providing medical care. Veterans who cannot receive needed medical care under Public Law 97-72 may be treated by the VA if they are eligible under any other law.

Figure 4. VA medical care available to eligible veterans of U.S. atmospheric nuclear testing and the occupation of Hiroshima and Nagasaki, Japan (Continued).

outpatient services to veterans who may have been exposed to ionizing radiation while in service at a nuclear test or during the Hiroshima/Nagasaki occupation (9). This care is not, however, available for disorders determined to be the result of causes other than exposure to ionizing radiation. Figure 4 underscores this point under the heading "Health Care Exceptions."

To receive VA health care, a veteran must have been at the site of nuclear testing or in occupied Hiroshima or Nagasaki. The veteran is asked to supply the following information to a VA official, who will transmit the data for confirmation to the appropriate NTPR team: name, branch of service, service number, social security number, name of test series, date of test series, and unit during test series (10).

A medical history, complete physical examination, and diagnostic studies will be done for each veteran requesting VA medical care under the provisions of Public Law 97-72. The examining physician is directed to pay particular attention to parts of the body most sensitive to ionizing radiation: the blood, thyroid, salivary glands, lung, bone marrow, and skin (10).

VA Circular 10-85-83, dated 28 May 1985, provides additional detail on VA health care services available to eligible veterans. This circular, current until 27 May 1986, is sent to all new callers on the NTPR toll-free telephone line, (800) 336-3068. (In Virginia, Hawaii, and Alaska, call collect to 703-285-5610.)

3.2.2 VA Service-Connected Disability Program.

Public Law 97-72 extends only to health care. Its provisions do not cover compensation for service-connected disease or disability, as indicated in figure 4 under "Claims for Compensation Benefits."

Public Law 98-542, enacted on 24 October 1984 as the "Veterans' Dioxin and Radiation Exposure Compensation Standards Act," required the VA to conduct rulemaking regarding its guidelines for the adjudication of compensation claims (11). The VA procedures formalized in response to this act were published in the Federal Register on 26 August 1985 and became effective on 25 September 1985. According to these procedures, the VA Chief of Benefits

Director reviews claims based on atmospheric nuclear test participation only if the following criteria are met: (1) The veteran was exposed to ionizing radiation as a result of participation in atmospheric nuclear weapons testing or the postwar occupation of Hiroshima or Nagasaki, Japan; (2) The veteran subsequently developed one of the illnesses listed below, each of which might be radiogenic; and (3) The illness became manifest during the specified time, also identified below (12).

The VA accepts the following illnesses as possibly being radiogenic:

- All forms of leukemia except chronic lymphatic leukemia
- Thyroid cancer
- Female breast cancer
- Lung cancer
- Bone cancer
- Liver cancer
- Skin cancer
- Esophageal cancer
- Stomach cancer
- Colon cancer
- Pancreatic cancer
- Kidney cancer
- Urinary bladder cancer
- Salivary gland cancer
- Multiple myeloma.

The rulings specify that the leukemia and bone cancer must become manifest within 30 years after exposure and that the other forms of cancer must become manifest within 5 years or more after exposure (12).

In reviewing a claim, the Chief Benefits Director considers such factors as the probable dose, the relative sensitivity of the involved tissue to induction of the specified condition by ionizing radiation, the veteran's gender and pertinent family history, the veteran's age at time of exposure, the time elapsed between exposure and onset of the disease, and possible contributions to the disease made by exposures to radiation or other carcinogens that were not service connected. The Chief Benefits Director may request an advisory medical opinion from the VA Chief Medical Director or from an outside consultant selected according to the provisions of its final rules. The Chief Benefits Director then submits his decision on the claim to the regional office of jurisdiction, which will make the final determination (12).

The VA requests assistance from the NTPR teams in documenting participation and determining radiation dose. The NTPR teams research all claims for the VA that have participation in the atmospheric nuclear tests as a basis. Chapter 2 identifies statistics on the numbers of these claims researched by the teams. Tables 5 through 8 provide statistics on NTPR responses to administrative claims for compensation from the VA. As noted in table 5, NTPR has given radiation dose information to the VA for 736 claims diagnosed as possibly radiogenic and for 1,566 claims diagnosed as non-radiogenic. Until September 1985, the VA always requested radiation dose information from NTPR on veterans of the atmospheric nuclear testing even if the veterans did not report an illness considered to be possibly radiogenic. The NTPR, in turn, sent letters to the VA asking if reported symptoms, such as dizziness or shortness of breath, were related to a radiogenic illness. Less than one percent of the replies from VA indicated an illness that could be radiogenic. At the time this volume went to press, the VA had yet to respond to 483 such requests for clarification. These 483 claims are listed in tables 5, 7, and 8 as non-radiogenic because of the information previously supplied by VA to DOD.

According to the VA, 83 of the veterans have been compensated, although only 23 have been compensated solely as a result of their radiation exposure. The remaining 60 veterans were compensated for other reasons, such as evidence that the illness became manifest while the veteran was still on active duty (13).

If a veteran believes his or her disease or disability resulted from radiation exposure incurred during U.S. atmospheric nuclear testing or the Hiroshima/Nagasaki occupation, he or she should file for benefits with the nearest VA regional office.

* * * * *

The first three chapters of this volume have introduced the NTPR program and the supporting organizations. The next two chapters describe the nuclear tests and identify personnel participation, the focus of the NTPR effort.

Table 5. Number of NTPR responses to VA claims relevant to the atmospheric nuclear detonations.

VA Radiation Exposure Claims	Number of NTPR Responses
Possibly Radiogenic	736
Non-Radiogenic	1,566
Total	2,302
Approved by VA	83

Table 6. Number of responses by U.S. military service to VA claims that might be radiogenic.

Possibly Radiogenic	Navy	Army	Air Force	Marine Corps	Total
Leukemia	37	30	8	6	81
Thyroid Cancer	4	4	1	1	10
Female Breast Cancer	0	0	0	0	0
Lung Cancer	88	75	30	25	218
Bone Cancer	9	5	1	2	17
Liver Cancer	3	7	7	4	21
Skin Cancer	115	61	38	19	233
Esophageal Cancer	5	6	1	3	15
Stomach Cancer	8	6	5	0	19
Colon Cancer	30	18	12	8	68
Pancreatic Cancer	6	4	2	2	14
Kidney Cancer	9	14	4	0	27
Urinary Bladder Cancer	14	8	11	5	38
Salivary Gland Cancer	2	2	0	2	6
Multiple Myeloma	10	11	4	2	27
Total	340	251	124	79	794*

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*Of the 736 claimants, 46 had more than one illness that might be radiogenic.

Table 7. Number of responses by U.S. military service to VA claims.

VA Radiation Exposure Claims	Navy	Army	Air Force	Marine Corps	Total
Possibly Radiogenic	325	232	108	71	736
Non-Radiogenic	720	580	158	108	1,566
Total	1,045	812	266	179	2,302

Table 8. Number of possibly radiogenic and non-radiogenic VA claims by test series and Hiroshima/Nagasaki occupation.

Operation	Possibly Radiogenic	Non-Radiogenic	Total
TRINITY	4	10	14
CROSSROADS	193	410	603
SANDSTONE	39	90	129
RANGER	6	6	12
GREENHOUSE	39	64	103
BUSTER-JANGLE	35	71	106
TUMBLER-SNAPPER	44	107	151
IVY	38	66	104
UPSHOT-KNOTHOLE	64	207	271
CASTLE	39	82	121
TEAPOT	49	79	128
WIGWAM	10	16	26
REDWING	29	70	99
PLUMBBOB	44	81	125
HARDTACK I	43	78	121
ARGUS	0	0	0
HARDTACK II	2	1	3
DOMINIC I	14	45	59
DOMINIC II/PLOWSHARE	1	3	4
HIROSHIMA/NAGASAKI OCCUPATION	79	129	208
Total	772	1,615	2,387*

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*Of the 2,302 veterans filing VA claims, 62 had attended more than one operation.

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SECTION 4

U.S. NUCLEAR TESTING FROM PROJECT TRINITY TO THE PLOWSHARE PROGRAM

The United States conducted Project TRINITY, the world's first nuclear detonation, in 1945. From 1946 to 1963, when the limited nuclear test ban treaty was signed, the U.S. conducted 18 atmospheric nuclear test series, identified below as operations, and a program of testing called PLOWSHARE. In addition, the U.S. staged safety experiments to determine the weapons' susceptibility to fission due to accidents in storage and transport. This chapter provides historical summaries of the tests, listed below in the order in which they occurred and are addressed:

- Project TRINITY, 1945 (CONUS)
- Operation CROSSROADS, 1946 (Oceanic)
- Operation SANDSTONE, 1948 (Oceanic)
- Operation RANGER, 1951 (CONUS)
- Operation GREENHOUSE, 1951 (Oceanic)
- Operation BUSTER-JANGLE, 1951 (CONUS)
- Operation TUMBLER-SNAPPER, 1952 (CONUS)
- Operation IVY, 1952 (Oceanic)
- Operation UPSHOT-KNOTHOLE, 1953 (CONUS)
- Operation CASTLE, 1954 (Oceanic)
- Operation TEAPOT, 1955 (CONUS)
- Operation WIGWAM, 1955 (Oceanic)
- Operation REDWING, 1956 (Oceanic)
- Operation PLUMBBOB, 1957 (CONUS)
- Operation HARDTACK I, 1958 (Oceanic)
- Operation ARGUS, 1958 (Oceanic)
- Operation HARDTACK II, 1958 (CONUS)
- Safety Experiments, 1955-1958 (CONUS)
- Operation DOMINIC I, 1962 (Oceanic)
- Operation DOMINIC II, 1962 (CONUS)
- PLOWSHARE Program, 1961-1962 (CONUS).

Most of the oceanic tests were conducted at the Pacific Proving Ground, which consisted principally of the Enewetak and Bikini Atolls in the northwestern Marshall Islands of the Pacific Ocean. The Marshall Islands are in the easternmost part of Micronesia. The Marshalls spread over about 2 million km^2 of the earth's surface, but the total land area is only about 180 km^2.* Two parallel chains form the islands: Ratak (or Sunrise) to the east, and Ralik (or Sunset) to the west; both Enewetak and Bikini are in the Ralik chain at its northern extreme. Figure 5 shows these islands in the central Pacific. It also indicates the locations of the Christmas and Johnston Islands, the sites for most of the DOMINIC I tests.

Most of the continental U.S. (CONUS) atmospheric tests were conducted at the Nevada Test Site (NTS). Established by the Atomic Energy Commission (AEC) in December 1950, the NTS is in the southeastern part of Nevada, 100 kilometers northwest of Las Vegas. Figure 6 shows the current NTS, an area of high desert and mountain terrain now encompassing approximately 3,500 square kilometers in Nye County. On its eastern, northern, and western boundaries, the NTS adjoins the Nellis Air Force Range.

The format of this chapter is generally consistent for the following sections, each of which summarizes a nuclear test series. The section begins by identifying the nuclear events and continues by discussing relevant background and objectives, test operations, and radiation doses. The NTPR teams provided data current as of 1 May 1986 on the radiation doses. The rest of the material derives from the volumes published by the Defense Nuclear Agency (DNA) on the nuclear test series. These volumes, listed in Appendix E, can be consulted for further information.

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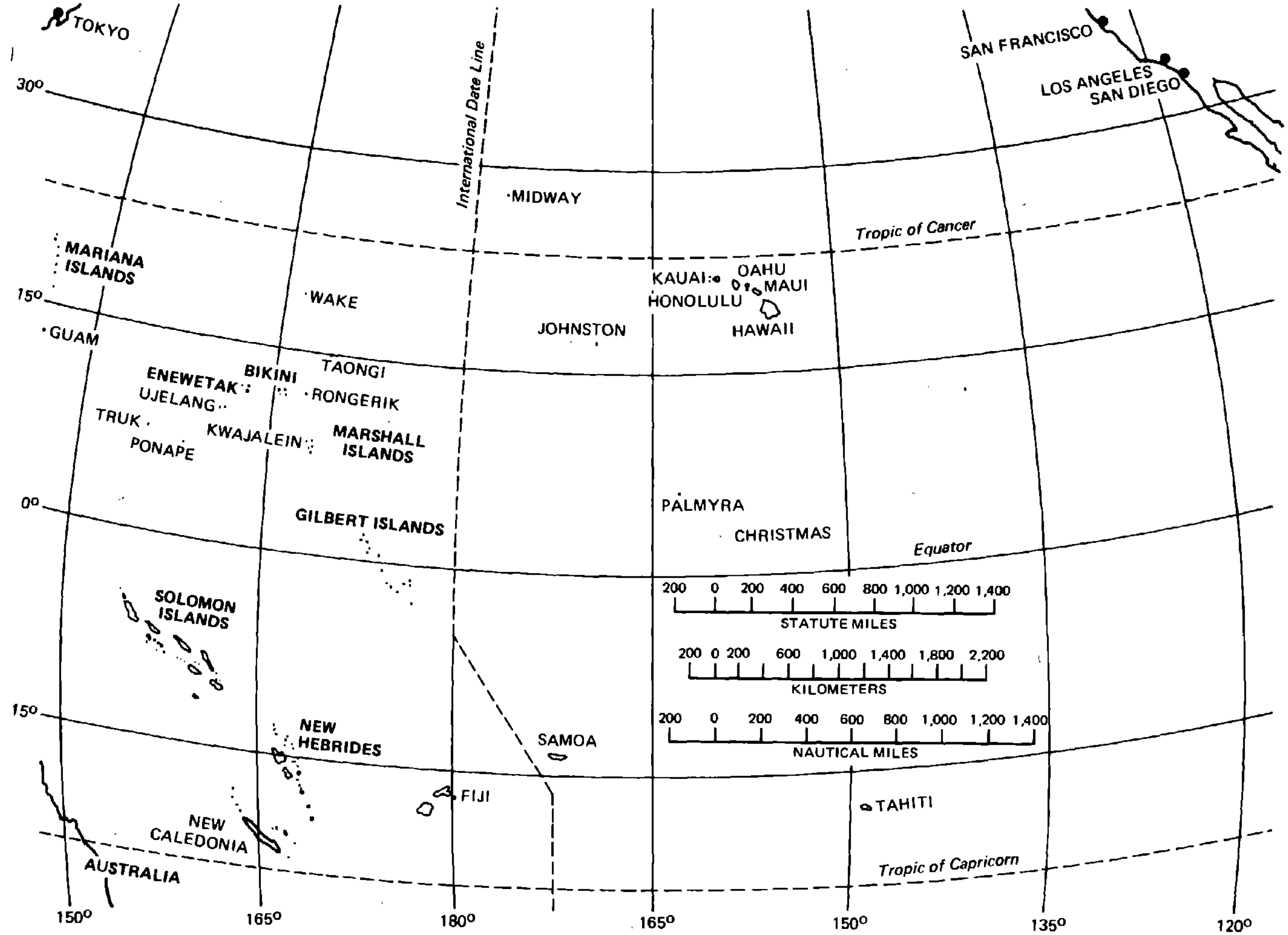
*Throughout this chapter, surface distances are given in metric units. The metric conversion factors include: 1 meter = 3.28 feet; 1 meter = 1.09 yards; and 1 kilometer = 0.62 miles. Vertical distances are given in feet; altitudes are measured from mean sea level, while heights are measured from surface level, unless otherwise noted.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GUAM
TAONGI
BIKINI
ENEWETAK
RONGERIK
UJELANG
TRUK
KWAJALEIN
MARSHALL ISLANDS
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GILBERT ISLANDS
CHRISTMAS
Equator
200 0 200 400 600 800 1,000 1,200 1,400
STATUTE MILES
200 0 200 600 1,000 1,400 1,800 2,200
KILOMETERS
SOLOMON ISLANDS
200 0 200 400 600 800 1,000 1,200 1,400
NAUTICAL MILES
15°
NEW HEBRIDES
SAMOA
FIJI
TAHITI
NEW CALEDONIA
AUSTRALIA
Tropic of Capricorn
150°
165°
180°
165°
150°
135°
120°

Figure 5. The Pacific Proving Ground.

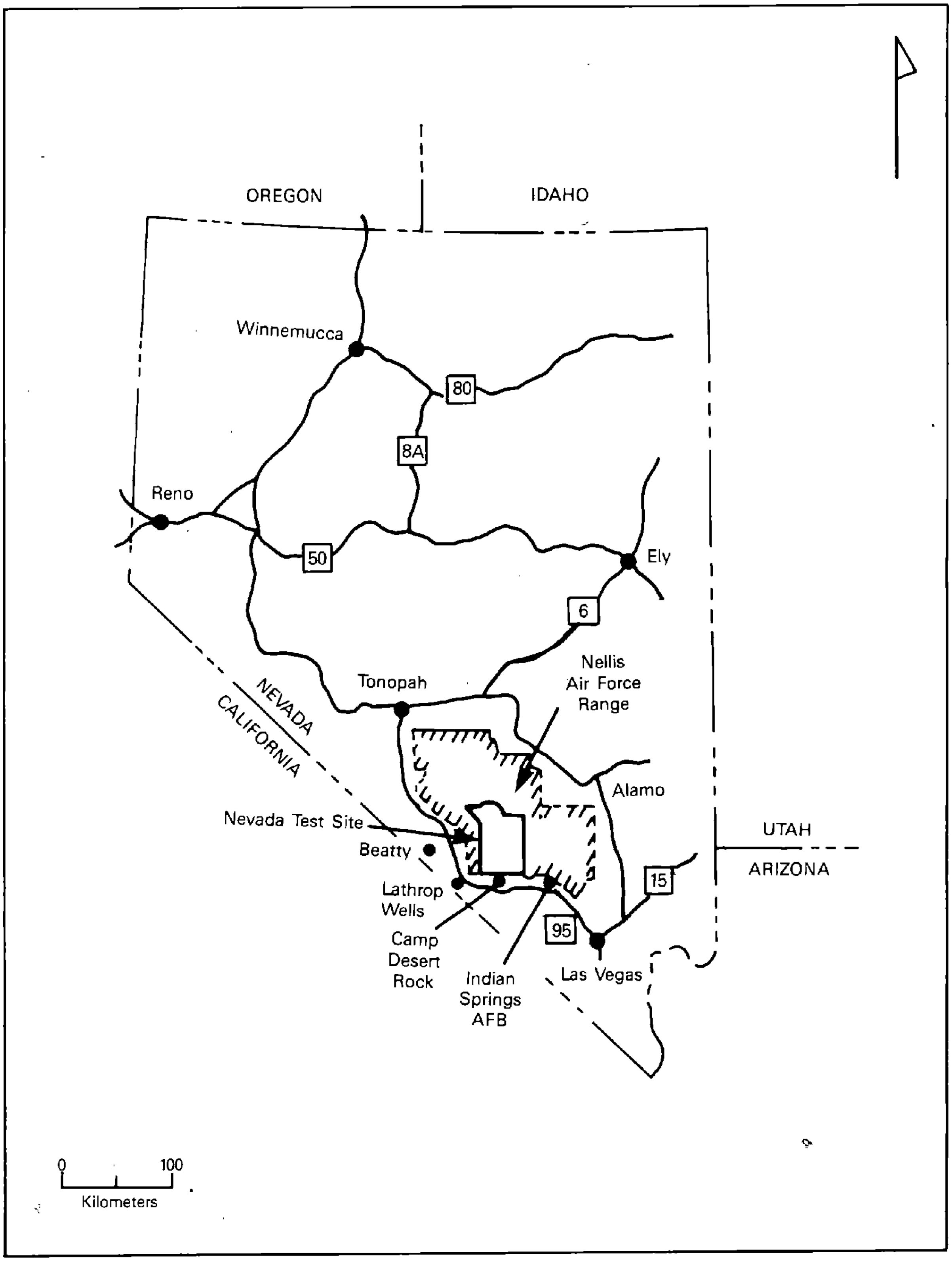

OREGON
IDAHO
Winnemucca
80
8A
Reno
50
Ely
6
Nellis
Air Force
Range
Tonopah
NEVADA
CALIFORNIA
Alamo
UTAH
ARIZONA
Nevada Test Site
Beatty
15
Lathrop
Wells
95
Camp
Desert
Rock
Indian
Springs
AFB
Las Vegas
0
100
Kilometers

Figure 6. The Nevada Test Site.

4.1 PROJECT TRINITY.

Project TRINITY was the first detonation of a nuclear weapon. The plutonium-fueled implosion device was detonated on a 100-foot tower at 0530 hours, 16 July 1945. The test, which occurred on the Alamogordo Bombing Range in south-central New Mexico, had a nuclear yield equivalent to the energy released by exploding 21 kilotons of TNT. It left a depression in the desert 2.9 meters deep and 335 meters wide (1: 1,23).

People as far away as Santa Fe and El Paso saw the brilliant light of the detonation. Windows rattled in the areas immediately surrounding the test site, waking sleeping ranchers and townspeople. To dispel any rumors that might compromise the security of this first nuclear test, the Government announced that an Army munitions dump had exploded. However, immediately after the bombing of Hiroshima, Japan, on 6 August 1945, the Government revealed to the public what had actually occurred in the New Mexico desert (1: 33).

4.1.1 Background and Objectives of Project TRINITY.

The United States' effort to develop a nuclear weapon came during World War II in response to the potential threat of a German nuclear weapon. On 6 December 1941, President Roosevelt appointed a committee to determine if the United States could construct a nuclear weapon. Six months later, the committee gave the President its report, recommending a fast-paced program that would cost up to $100 million and that might produce the weapon by July 1944 (1: 12,13).

The President accepted the committee's recommendation. The effort to construct the weapon was turned over to the War Department, which assigned the task to the Army Corps of Engineers. In September 1942, the Corps of Engineers established the Manhattan Engineer District (MED), under the command of Major General Leslie Groves, to oversee the development of a nuclear weapon. This effort was code named the "Manhattan Project" (1: 13).

During the first 2 years of the Manhattan Project, work proceeded at a slow but steady pace. Significant technical problems had to be solved, and difficulties in the concentration of uranium-235 and production of plutonium, particularly the inability to process large amounts, often frustrated the scientists. Nonetheless, by 1944 sufficient progress had been made to persuade the scientists that their efforts might succeed. A test of the plutonium implosion device was necessary to determine if it would work and what its effects would be. Led by Dr. J. Robert Oppenheimer, Manhattan Project scientists at Los Alamos Laboratory (later to become the Los Alamos National Laboratory) were "to make preparations for a field test in which blast, earth shock, neutron and gamma radiation would be studied and complete photographic records made of the explosion and any atmospheric phenomena connected with the explosion" (1: 13,14).

The planned firing date for the TRINITY device was originally 4 July 1945. On 14 June 1945, Dr. Oppenheimer changed the test date to no earlier than 13 July and no later than 23 July. On 30 June, the earliest firing date was moved to 16 July, even though better weather was forecast for 18 and 19 July. The TRINITY test organization adjusted the schedule because the Allied conference in Potsdam, Germany, was about to begin and the President needed the results of the test as soon as possible (1: 26).

On 6 August 1945, 3 weeks after the detonation of TRINITY, the first uranium-fueled nuclear bomb, a gun-type weapon code named LITTLE BOY, was detonated over Hiroshima. On 9 August, FAT MAN, a plutonium-fueled implosion weapon with the same design as the TRINITY device, was detonated over another Japanese city, Nagasaki. Two days later, the Japanese Government informed the United States of its decision to surrender. On 2 September 1945, Japan officially surrendered to the Allied Governments, thereby bringing World War II to an end (1: 11).

4.1.2 TRINITY Test Operations.

From 16 July 1945 through 1946, about 1,000 military and civilian personnel took part in Project TRINITY or visited the test site. All participants, civilian as well as military, were under the authority of the MED. Project activities included scientific studies. Military exercises were not conducted at TRINITY (1: 1).

The Los Alamos Laboratory, which was staffed and administered by the University of California (under contract to the MED), conducted diagnostic experiments. Before the detonation, civilian and military scientists and technicians, assisted by other military personnel, placed gauges, detectors, and other instruments around ground zero. Four offsite monitoring posts were established in the towns of Nogal, Roswell, Socorro, and Fort Sumner, New Mexico. An evacuation detachment consisting of 144 to 160 enlisted men and officers was established in case protective measures or evacuation of civilians living offsite became necessary. Such action was not deemed necessary, however, and the evacuation detachment was dismissed late on the day of the detonation for return to Los Alamos (1: 1).

For the detonation, at least 263 DOD participants were at the test site. Among this group were 99 personnel occupying shelters approximately 9,175 meters north, south, and west of ground zero. No one was closer to ground zero at shot-time (1: 31).

To determine the extent of the radiation resulting from the detonation, a network of detectors with remote read-out was installed along routes between ground zero and each shelter. In addition, trained monitors with portable radiation survey instruments were assigned to each shelter. No radiation was detected at the south and west shelters. The remote detectors north of ground zero indicated that the radioactive cloud was moving in that direction, and a monitor in the north shelter observed a sharp increase in the radiation level. The shelter was consequently evacuated shortly after the detonation. It was learned later that the monitor had inadvertently changed an adjustment on his instrument, which resulted in a false reading. Very little contamination occurred at the north shelter (1: 1,2).

A substantial amount of activity took place at the test site during the first 3 days following the detonation, as scientists entered the ground zero area to retrieve instruments or to perform experiments. Their entry into, activities at, and exit from the test site were carefully controlled. When the itinerary indicated operations in regions of known radiation intensity, a limit was set on the time spent in the area. Radiation detectors were provided, when possible, to permit continuous monitoring of the exposure. Film badges were also provided to each person for subsequent determination and recording of the doses received. The number of personnel at the TRINITY test site diminished rapidly after 19 July, as the emphasis shifted to preparing the devices that were to be used over Japan (1: 38).

4.1.3 Dose Summary for Project TRINITY.

The dose limit for TRINITY participants was 5.0 rem (roentgen equivalent man) of gamma radiation during a 2-month period (2: 29). The table below summarizes the available dosimetry information:

Summary of External Doses for Project TRINITY as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	103	15	30	10	1	1
Navy	2	0	2	0	0	0

4.2 OPERATION CROSSROADS.

Conducted in 1946 at Bikini, CROSSROADS involved approximately 42,000 personnel, 251 ships, and 156 aircraft. The series consisted of an airdrop detonated at a height of 520 feet and an underwater shot conducted at a depth of 90 feet:

Event	Date	Type	Yield (kilotons)
ABLE	1 July	Airdrop	21
BAKER	25 July	Underwater	21

The nuclear devices were similar to the TRINITY device and to the weapon detonated over Nagasaki, Japan (3: 17).

Among the numerous observers of these two detonations was an Army doctor trained as a radiological safety monitor. He made the following observations of ABLE and BAKER from a Navy aircraft approximately 20 nautical miles from each detonation:

> ABLE: At twenty miles [it] gave us no sound or flash or shock wave. . . . Then, suddenly we saw it -- a huge column of clouds, dense, white, boiling up through the strato-cumulus, looking much like any other thunderhead but climbing as no storm cloud ever could. The evil mushrooming head soon began to blossom out. It climbed rapidly to 30,000 or 40,000 feet, growing a tawny-pink from oxides of nitrogen, and seemed to be reaching out in an expanding umbrella overhead. . . . For minutes the cloud stood solid and impressive, like some gigantic monument, over Bikini. Then finally the shearing of the winds at different altitudes began to tear it up into a weird zigzag pattern (4: 55).

> BAKER: This shot in broad day, at fifteen miles, seemed to spring from all parts of the target fleet at once. A gigantic flash -- then it was gone. And where it had been now stood a white chimney of water reaching up and up. Then a huge hemispheric mushroom of vapor appeared like a parachute suddenly opening. . . . By this time the great geyser had climbed to several thousand feet. It stood there as if solidifying for many seconds, its head enshrouded in a tumult of steam. Then slowly the pillar began to fall and break up. At its base a tidal wave of spray and steam arose, to smother the fleet and move on toward the islands. All this took only a few seconds, but the phenomenon was so astounding as to seem to last much longer (4: 93).

Figure 7 shows the BAKER detonation (A). Credits for figure 7 and the subsequent photographs follow the references at the end of this chapter.

4.2.1 Background and Objectives of CROSSROADS.

After the atomic bomb attacks on Japan had abruptly ended World War II, many military leaders felt that military science was at a crossroads. The admiral who directed CROSSROADS declared that "warfare, perhaps civilization itself, had been brought to a turning point by this revolutionary weapon." With this thought in mind, he named the initial postwar test series (3: 17).

As early as August 1945, the Chairman of the Senate's Special Committee on Atomic Energy proposed that the effectiveness of atomic bombs be demonstrated on captured Japanese ships. In September, the Commanding General of the Army Air Forces put the question of such a test before the Joint Chiefs of Staff (JCS). The ensuing discussion and recommendations led President Harry

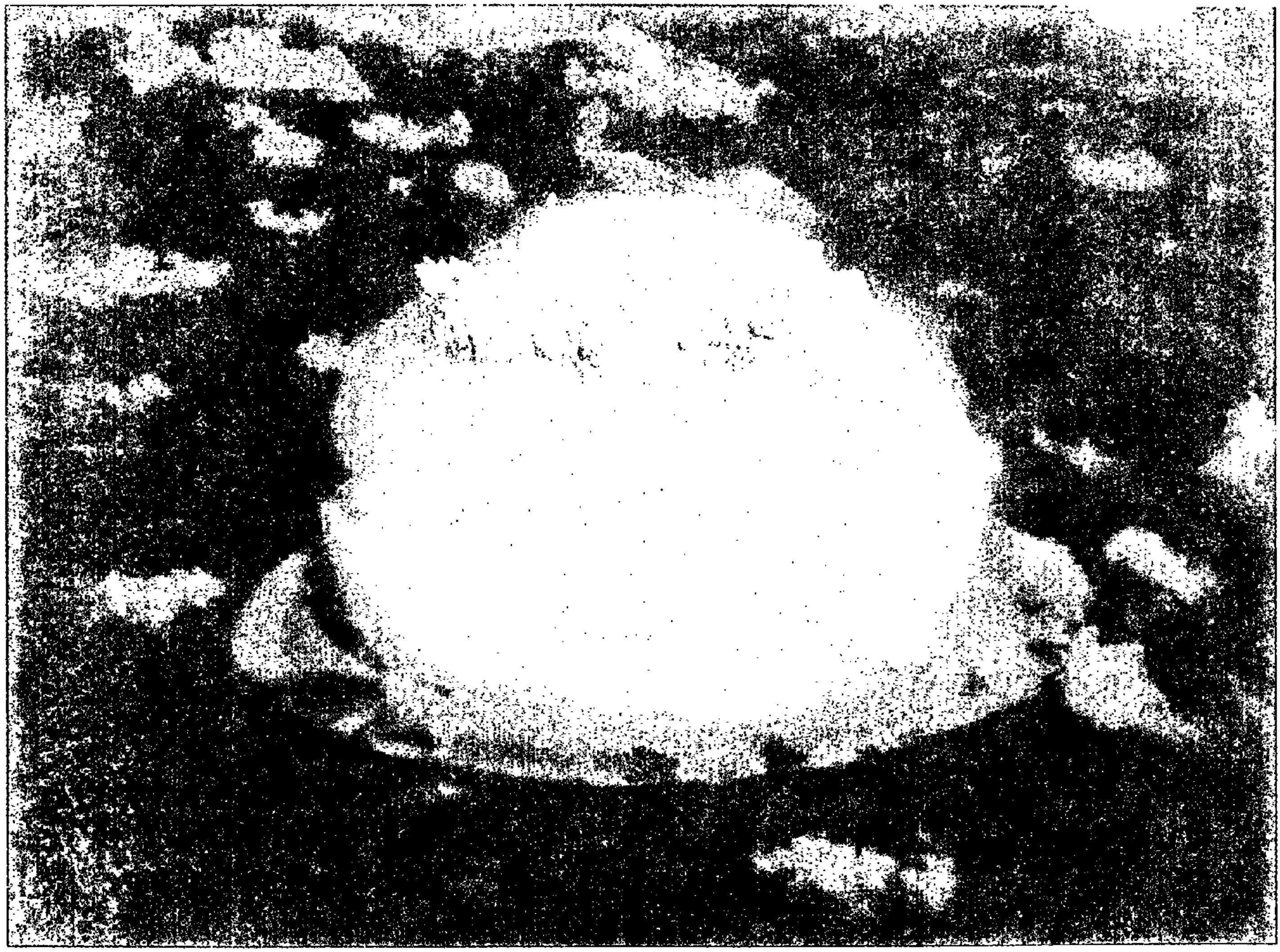


Figure 7. Shot BAKER emerging amidst the unmanned target fleet, 25 July 1946.

Truman to announce, on 10 December 1945, that the U.S. would further explore the capabilities of atomic energy in the form of scientific atomic bomb tests under JCS jurisdiction (3: 18).

CROSSROADS was designed to produce information not available from the TRINITY test or the Hiroshima and Nagasaki bombings. The primary purpose was to determine the effects of atomic bombs on naval vessels. The secondary purposes were to provide training for aircrews in attack techniques using atomic bombs against ships and to determine atomic bomb effects upon other military equipment and installations (3: 18).

4.2.2 CROSSROADS Test Operations.

A fleet of more than 90 target vessels was assembled in Bikini Lagoon for CROSSROADS. The target fleet consisted of older U.S. ships, such as the aircraft carriers USS Saratoga and the USS Independence, the battleships USS Nevada, USS Arkansas, USS Pennsylvania, and USS New York, surplus U.S. cruisers, destroyers, submarines, and a large number of auxiliary and amphibious vessels. The German cruiser Prinz Eugen and two major captured Japanese ships, the battleship Nagato and the cruiser Sakawa, also were targets. The support fleet comprised more than 150 ships that provided quarters, experimental stations, and workshops for most of the approximately 42,000 participants, more than 37,000 of whom were Navy personnel (3: 1,84).

ABLE operations went smoothly. The radioactivity created by the airburst had only a transient effect. Within a day, radiation intensities in the lagoon had decayed to less than 0.1 R/24 hours, and nearly all the surviving target ships had been safely reboarded. The ship inspections, instrument recoveries, and remooring necessary for the BAKER test proceeded on schedule (3: 1,217).

BAKER, on the other hand, presented difficulties. The underwater detonation caused most of the target fleet to be bathed in radioactive water spray and radioactive debris. With the exception of 12 target vessels in the lagoon and the landing craft beached on Bikini Island, the surviving target fleet was too radiologically contaminated for many days for more than brief on-board activities. During the first week of August, attempts were made to decontaminate the vessels. By 10 August, upon the advice of the Chief of the Radiological Safety Division, the Task Force Commander decided to terminate these efforts and tow most of the remaining target fleet to Kwajalein Atoll for possible decontamination (3: 2).

In the latter half of August 1946, the surviving target ships were towed or sailed to Kwajalein Atoll. Eight of the major ships and two submarines were towed back to the U.S. for radiological inspection. Twelve target ships were so lightly contaminated that their crews remanned them and sailed them back to the United States. The remaining target ships were destroyed by sinking off Bikini Atoll, off Kwajalein Atoll, or near the Hawaiian Islands during 1946-1948. The support ships were decontaminated as necessary at U.S. Navy shipyards, primarily in San Francisco and in Bremerton, Washington (3: 2).

4.2.3 Dose Summary for CROSSROADS.

CROSSROADS operations were undertaken under radiological supervision intended to keep personnel doses below 0.1 rem of gamma radiation per day. About 15 percent of the participants were issued film badges. Personnel anticipated to have the most potential for exposure were badged, and a percentage of each group working in less radioactive areas were badged (3: 2,3).

Because radiation dose data are not complete, reconstructions have been made of personnel doses for unbadged crewmembers of the ships involved. The calculations relied upon the radiation measurements recorded by radiation safety personnel in 1946 and used the types of methods discussed in chapter 7. The table below summarizes the available dosimetry information:

Summary of External Doses for Operation CROSSROADS
as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	3,250	25	15	10	0	0
Navy	28,436	4,883	2,939	4	0	0
Marine Corps	550	0	0	0	0	0

4.3 OPERATION SANDSTONE.

Conducted at the Enewetak Atoll in 1948, Operation SANDSTONE consisted of three tower shots, all detonated at a height of 200 feet (5: 1):

Event	Date	Type	Yield (kilotons)
X-RAY	15 April	Tower	37
YOKE	1 May	Tower	49
ZEBRA	15 May	Tower	18

4.3.1 Background and Objectives of Operation SANDSTONE.

Operation SANDSTONE was the second test series carried out in the Marshall Islands. It differed from the first, CROSSROADS, in that it was primarily a scientific series conducted by the Atomic Energy Commission. The AEC was activated on 1 January 1947 to assume the responsibilities formerly held by the Manhattan Engineer District, dissolved at the end of 1946. The Armed Forces had a supporting role in SANDSTONE, whereas they had assumed a lead role in CROSSROADS (5: 1).

SANDSTONE was a proof-test of second-generation nuclear devices. The two weapons detonated at CROSSROADS were the same type of weapon dropped on Nagasaki. On 3 April 1947, the General Advisory Committee to the AEC recommended development and testing of new weapons. When the President approved the preliminary SANDSTONE test program on 27 June 1947, the U.S. apparently had only 13 nuclear weapons in its stockpile. One year later, despite heavy emphasis on increased production of fissionable material, the number of weapons was only about 50, far short of the number that military planners calculated would be required in a war with the Soviet Union. The great expansion in the U.S. stockpile evident by the end of 1949 was the direct result of the higher production rates of fissionable material and the more efficient weapons designs proof-tested at SANDSTONE (5: 17,18).

Meetings were held on 9 July 1947 at Los Alamos, New Mexico, to define test responsibilities for SANDSTONE. The Los Alamos National Laboratory (LANL), the organization that had developed the wartime atomic weapons and that did research and laboratory development of new nuclear weapons designs, was to provide technical leadership and the military services were to provide supplies and support (5: 18).

4.3.2 SANDSTONE Test Operations.

Numerous technical experiments were conducted in conjunction with each of the three detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the events. The studies were similar at each of the shots but were carried out more precisely with YOKE and ZEBRA as collective experience grew (5: 2,102).

Peak DOD numerical strength at SANDSTONE was approximately 11,500 participants, 95 percent of whom were military personnel. The DOD personnel had support roles and some had duty stations at the AEC weapons design and development laboratories or were part of units performing separate experiments (5: 1,2).

4.3.3 Dose Summary for Operation SANDSTONE.

The dose limit for SANDSTONE participants was 0.1 rem of gamma radiation per 24-hour period and a maximum 3.0 rem for certain approved and specific missions (5: 2). The following table summarizes the available dosimetry information:

Summary of External Doses for Operation SANDSTONE as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	1,703	2	7	0	1	0
Navy	7,731	17	9	1	1	0
Air Force	2,075	27	8	1	0	0
Marine Corps	180	1	1	0	0	0
Civilian DOD Participants	17	0	0	0	0	0

4.4 OPERATION RANGER.

Operation RANGER was the first atmospheric nuclear weapons test series conducted by the Atomic Energy Commission at the Nevada Test Site. This 1951 series consisted of five nuclear events, all of which were airdrops detonated at heights of about 1,000-1,400 feet. In addition, RANGER included one non-nuclear high-explosive test detonated 2 days before the first nuclear event. The following table provides specifics on the nuclear shots (6: 1,4):

Event	Date	Type	Yield (kilotons)
ABLE	27 January	Airdrop	1
BAKER	28 January	Airdrop	8
EASY	1 February	Airdrop	1
BAKER-2	2 February	Airdrop	8
FOX	6 February	Airdrop	22

4.4.1 Background and Objectives of Operation RANGER.

In November 1950, the Los Alamos National Laboratory discovered that insufficient data were available to determine satisfactory design criteria for nuclear devices to be tested in Operation GREENHOUSE, a series of AEC nuclear tests scheduled for the Pacific from 7 April through 24 May 1951. The LANL scientists believed that variations in the compression of the critical material could affect the yields of the GREENHOUSE devices. To confirm this hypothesis, LANL held conferences on 6 and 11 December 1950 and concluded that a series of small nuclear tests should be conducted to improve the GREENHOUSE design criteria. On 22 December 1950, LANL requested approval for a continental series from the AEC Division of Military Application (DMA). DMA approved the request and asked for Presidential approval to expend the fissionable material required for the series and to use part of the Las Vegas Bombing and Gunnery Range in Nevada for the tests. The White House responded affirmatively to both requests on 11 January 1951, formally creating Operation RANGER (6: 18).

The same day that Operation RANGER was approved by the President, the AEC distributed its only announcements of the coming tests. Handbills were circulated in the area of the test site, stating that from 11 January 1951 the Government would be conducting nuclear tests at the Las Vegas Bombing and Gunnery Range. Figure 8 shows this handbill (6: 18-20).

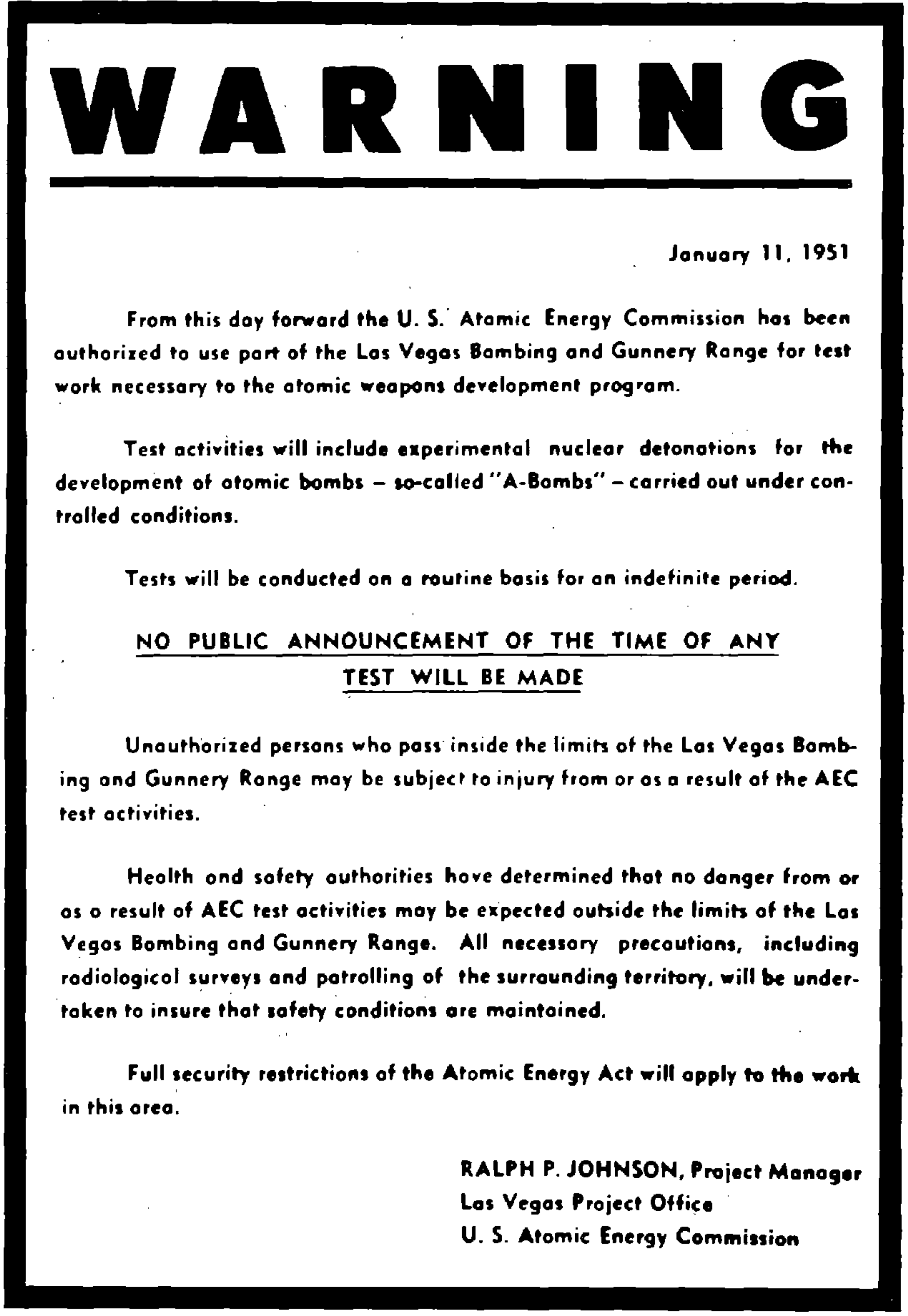
4.4.2 Establishment of the Nevada Test Site.

Nearly 6 years passed between the detonation of TRINITY at Alamogordo, New Mexico, on 16 July 1945, and the next CONUS nuclear test, ABLE of the RANGER series. The AEC had considered establishing a continental test site in 1948 after SANDSTONE, as a way to reduce construction and logistic costs, but rejected the idea after concluding that the physical problems and domestic political concerns would be too complicated. When the Korean War began in the summer of 1950, however, the AEC doubted that the Pacific could be used for nuclear weapons testing because of the possibility of the Korean War expanding throughout the Far East, thus endangering shipping lanes. On 13 July 1950, the AEC Chairman wrote the Chairman of the Military Liaison Committee that the possibility of a national emergency required a joint effort by the AEC and DOD to find a continental test site. The DOD agreed, and the search began for a suitable site.

The AEC and DOD surveyed six sites within the continental United States before choosing the Frenchman Flat area of the Las Vegas Bombing and Gunnery Range, renamed the Nellis Air Force Range in 1956. The Government picked this site because it best suited AEC criteria for favorable meteorological conditions, distance from population areas, and proximity to operational facilities (6: 19-20). Known first as the Nevada Test Site (NTS), then as the Nevada Proving Ground (NPG) beginning in early 1952, the site since 1955 has again been called the Nevada Test Site, the designation used throughout this volume.

4.4.3 RANGER Test Operations.

Only about 280 DOD personnel took part in RANGER, which was primarily an AEC activity. They were engaged in support services, scientific experiments, weather support, communications security, and observer activities. The



WARNING

January 11, 1951

From this day forward the U. S. Atomic Energy Commission has been authorized to use part of the Las Vegas Bombing and Gunnery Range for test work necessary to the atomic weapons development program.

Test activities will include experimental nuclear detonations for the development of atomic bombs – so-called "A-Bombs" – carried out under controlled conditions.

Tests will be conducted on a routine basis for an indefinite period.

NO PUBLIC ANNOUNCEMENT OF THE TIME OF ANY TEST WILL BE MADE

Unauthorized persons who pass inside the limits of the Las Vegas Bombing and Gunnery Range may be subject to injury from or as a result of the AEC test activities.

Health and safety authorities have determined that no danger from or as a result of AEC test activities may be expected outside the limits of the Las Vegas Bombing and Gunnery Range. All necessary precautions, including radiological surveys and patrolling of the surrounding territory, will be undertaken to insure that safety conditions are maintained.

Full security restrictions of the Atomic Energy Act will apply to the work in this area.

RALPH P. JOHNSON, Project Manager
Las Vegas Project Office
U. S. Atomic Energy Commission

Figure 8. AEC handbill announcing the beginning of the RANGER tests.

majority participated in the air support services conducted primarily by Air Force personnel from the Special Weapons Command (SWC) and Headquarters, Air Force. At each event, air support activities included the airdrop of the nuclear device, cloud sampling, cloud tracking, aerial surveys of the terrain, and courier service. Air Force personnel also provided meteorological services and communications security and monitored worldwide radioactivity from the RANGER test for the Atomic Energy Detection System. Since RANGER was only a 13-day operation, the same units and participants performed the same duties throughout the series (6: 1).

4.4.4 Dose Summary for Operation RANGER.

The summary table given below indicates that four doses exceeded the 3.0-rem limit of gamma radiation per 13-week period (6: 3):

Summary of External Doses for Operation RANGER as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	8	2	2	2	0	0
Navy	3	1	0	1	1	0
Air Force	213	0	0	0	0	0
Marine Corps	0	1	0	0	0	0
Civilian DOD Participants	17	6	9	0	0	0

4.5 OPERATION GREENHOUSE.

GREENHOUSE was the fourth postwar atmospheric nuclear weapons test series. Conducted in 1951 on the northeastern islands of the Enewetak Atoll, the series consisted of four tower shots, two at 200 feet and two at 300 feet (7: 1):

Event	Date	Type	Yield (kilotons)
DOG	8 April	Tower	NA*
EASY	21 April	Tower	47
GEORGE	9 May	Tower	NA
ITEM	25 May	Tower	NA

*Not announced

4.5.1 Background and Objectives of Operation GREENHOUSE.

The purpose of the four GREENHOUSE tests was to continue development of nuclear weapons for defense. More specifically, work was proceeding at this time on developing thermonuclear weapons, and the GREENHOUSE tests were part of this process (7: 1).

In 1949, the Soviet Union detonated its first atomic bomb, providing the impetus for the United States to proceed with development of a bomb whose energy would come from the fusion, or joining, of light elements. Such a weapon is also called a thermonuclear, or hydrogen, bomb. The Atomic Energy Commission received Presidential approval for work in this area in January 1950 after lengthy debate in high defense circles over the feasibility and advisability of such weapons (7: 21).

Although the GREENHOUSE nuclear devices were not thermonuclear devices, two of them involved thermonuclear experiments, and one test, GEORGE, was an important step toward thermonuclear devices. GEORGE demonstrated the initiation of a sustained thermonuclear reaction by use of a fission reaction. This led directly to the first successful thermonuclear test, MIKE (Operation IVY), some 16 months later. In addition, ITEM, the fourth test of the series, involved boosting the efficiency of fission explosions. Development of this experiment had been planned before the Soviet test in 1949 (7: 21).

4.5.2 GREENHOUSE Test Operations.

The Navy had provided most of the personnel for the earlier Pacific nuclear test series. It contributed the largest number to GREENHOUSE, too, but the Army and Air Force were also well represented, as the following numbers show (7: 1):

Organization	Estimated Number of Participants
Army	1,500
Navy	2,900
Air Force	2,550
Marine Corps	80
Civilian DOD Participants	560
Total	7,590

Participants supported the eight GREENHOUSE scientific programs, which consisted of projects recommended by the Army, Navy, Air Force, Armed Forces Special Weapons Project (AFSWP), and the Atomic Energy Commission. The programs were of three types: those dealing with the chemistry and physics of atomic explosions; those dealing with the effects of such explosions on the natural environment, on man-made objects, and on various plants and animals; and those designed to help develop means to detect nuclear detonations at great distances so that U.S. authorities could monitor nuclear developments in other countries (7: 130).

4.5.3 Dose Summary for Operation GREENHOUSE.

The maximum permissible dose for Operation GREENHOUSE participants was 0.1 rem of gamma radiation per day (0.7 rem per week), not to exceed a total of 3.9 rem for 13 weeks. A total of up to 3.0 rem on any one day could be authorized in specific cases. When this authorization was made, however, individuals were not to exceed 0.1 rem per day during the remainder of the operation (7: 64).

Film badges were issued to individuals who might be exposed to radiation while performing their duties. In addition, over 75 film badges for each test were distributed among the six participating ships, to be worn from the day of the test to 7 days thereafter. Among the men in the test area during all or part of the testing operations, 2,416 were badged one or more times (7: 2).

Fallout occurred on the inhabited islands of Enewetak, Parry, and Japtan and on the six task force ships after three of the four shots in the series. Fallout from Shot DOG was approximately twice as great on Parry and Japtan than it was on Enewetak, where the majority of the island-based participants were located. Shot EASY fallout was insignificant and affected all residence islands equally. Shot ITEM fallout, on the other hand, was approximately twice as great on Enewetak as it was on Japtan (7: 3). Overall, calculated fallout doses for personnel remaining on the residence islands until the end of May, when the rollup phase was virtually complete, were nearly equal on all three of the islands: Enewetak, 2.93 rem; Parry, 3.10 rem; and Japtan, 2.87 rem.

The amount of fallout received by the six ships varied with their locations and decontamination procedures. Nearly all crewmembers on five of these ships were assigned a fallout dose immediately after GREENHOUSE, and these doses were recorded in Navy medical records. The assigned doses ranged from 0.334 rem on USS LST-859 to 1.1 rem on USS Cabildo (LSD-16) and USS Sproston (DDE-577). Boat pool doses ranged from 0.700 to 2.1 rem. The fallout exposure was lower aboard ship than on the islands due to water washdown, shielding, and decontamination of external surfaces (7: 3).

Summary of External Doses for Operation GREENHOUSE as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	105	80	115	1,174	26	0
Navy	1,045	481	1,137	180	56	4
Air Force	721	326	223	1,022	214	14
Marine Corps	4	0	41	1	1	0
Civilian DOD Participants	356	67	96	42	0	0

4.6 OPERATION BUSTER-JANGLE.

Conducted from 22 October to 29 November 1951, Operation BUSTER-JANGLE was the second series of atmospheric nuclear weapons tests at the NTS. The series consisted of seven nuclear detonations, summarized below:

Event	Date	Type	Yield (kilotons)
ABLE	22 October	Tower	<0.1
BAKER	28 October	Airdrop	3.5
CHARLIE	30 October	Airdrop	14
DOG	1 November	Airdrop	21
EASY	5 November	Airdrop	31
SUGAR	19 November	Surface	1.2
UNCLE	29 November	Underground	1.2

SUGAR was the first surface and UNCLE the first underground (-17 feet) detonation of a nuclear device (8: 1,6).

4.6.1 Background and Objectives of Operation BUSTER-JANGLE.

This series was originally planned as two separate weapons testing programs: Operation BUSTER and Operation JANGLE. BUSTER, the plans for which began in late 1950, was to evaluate new devices developed by the Los Alamos National Laboratory and to obtain data on the basic phenomena associated with these devices. Plans for JANGLE originated with Operation CROSSROADS, conducted at Bikini in 1946. Scientific studies of the underwater CROSSROADS detonation led to inquiries concerning the effects and possible military value of an underground nuclear detonation. The Joint Chiefs of Staff accordingly obtained AEC agreement to conduct tests involving an underground and a surface nuclear detonation. The general objectives of the tests were to determine the effects of these detonations and to study the devices for inclusion in the nuclear arsenal (8: 20-21).

In 1950, AEC and DOD representatives selected Amchitka Island, one of the Aleutian Islands, as the site for the underground and surface tests, to be called Operation WINDSTORM and to be conducted from 15 September to 15 November 1951. During March 1951, they decided that the tests should be conducted at the NTS and should be coordinated by the Air Force. The two nuclear events were subsequently renamed Operation JANGLE (8: 21).

Because BUSTER and JANGLE were then both scheduled for the fall of 1951 at the NTS, the Armed Forces Special Weapons Project recommended that the two series be conducted as consecutive phases of one series, Operation BUSTER-JANGLE. On 19 June 1951, the AEC approved the AFSWP recommendation (8: 21-22).

4.6.2 BUSTER-JANGLE Test Operations.

Operation BUSTER-JANGLE involved an estimated 7,800 DOD personnel in observer programs, tactical maneuvers, damage effects tests, scientific and diagnostic studies, and support activities. Approximately 6,500 of these participants took part in Exercises Desert Rock I, II, and III, Army programs involving members from all four armed services. The remaining DOD personnel provided support for the Desert Rock exercises or participated in scientific activities (8: 1).

Exercise Desert Rock I was conducted at Shot DOG, and Exercises Desert Rock II and III at Shots SUGAR and UNCLE, respectively. The troop exercises were the first staged by the Armed Forces during continental nuclear weapons testing. The Desert Rock exercises included observer programs, tactical maneuvers, and damage effects tests. Observer programs, conducted at DOG, SUGAR, and UNCLE, generally involved briefings on nuclear weapons effects, observation of the nuclear detonation, and a subsequent tour of a display of military equipment exposed to the detonation. Tactical maneuvers, conducted after DOG, were designed both to train troops and to test military tactics. Damage effects tests, at DOG, SUGAR, and UNCLE, were performed to determine the effects of a nuclear detonation on military equipment and field fortifications (8: 1).

4.6.3 Dose Summary for Operation BUSTER-JANGLE.

The AEC established a dose limit of 1.0 rem of gamma radiation for participants in Exercise Desert Rock I and a limit of 3.0 rem for the following: participants in Exercises Desert Rock II and III; the test organization, which coordinated BUSTER-JANGLE; and Special Weapons Command, which provided weather and air support, among other functions, for the test organization. SWC sampling pilots and crews were authorized to receive up to 3.9 rem because their mission required them to penetrate the clouds resulting from the detonations (8: 4). The following table summarizes the available dosimetry information:

Summary of External Doses for Operation BUSTER-JANGLE as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	6,503	85	33	5	4	0
Navy	156	57	90	16	0	0
Air Force	502	16	45	18	0	0
Marine Corps	186	0	2	0	0	0
Civilian DOD Participants	65	4	20	3	0	0

4.7 OPERATION TUMBLER-SNAPPER.

Operation TUMBLER-SNAPPER, conducted from 1 April to 5 June 1952, was the third series of nuclear weapons tests at the NTS. The operation consisted of eight nuclear detonations, identified below:

Event	Date	Type	Yield (kilotons)
ABLE	1 April	Airdrop	1
BAKER	15 April	Airdrop	1
CHARLIE	22 April	Airdrop	31
DOG	1 May	Airdrop	19
EASY	7 May	Tower	12
FOX	25 May	Tower	11
GEORGE	1 June	Tower	15
HOW	5 June	Tower	14

The detonations were part of two phases of the series, as explained in the next section (9: 1,9).

4.7.1 Background and Objectives of Operation TUMBLER-SNAPPER.

As the defense policy evolved in the early 1950s, two particular factors challenged the ability of U.S. Armed Forces to defend American interests and to protect its allies during limited hostilities:

- The commitment of U.S. ground forces to the Korean peninsula
- The inability of European allies of the U.S. to develop effective military capabilities.

In both cases, the United States experienced difficulties because of limitations in military manpower, which emphasized the need for a new U.S. policy based not on large standing armies, but on new technological advances, particularly in nuclear weapons (9: 25).

In 1951, the Chairman of the AEC strongly advocated the development of nuclear weapons for tactical purposes. "We could," he asserted, "use an atomic bomb today in a tactical way against enemy troops in the field, against military concentrations near battle areas and against other vital military targets without risk to our own troops." TUMBLER-SNAPPER was accordingly designed both to advance the development of effective nuclear weapons and to train troops in tactical nuclear warfare (9: 25).

The series, like BUSTER-JANGLE, was originally planned as two separate testing programs: Operation TUMBLER, to be conducted at the NTS before 1 May 1952; and Operation SNAPPER, scheduled to begin at the NTS on 1 May 1952. Because the programs planned for the two series sometimes overlapped, they were combined into one operation, TUMBLER-SNAPPER (9: 26-28).

The series consisted of two phases. The TUMBLER phase, of primary concern to the DOD, featured four weapons effects tests: ABLE, BAKER, CHARLIE, and DOG. These airdropped devices were detonated to collect information on the effect of the height of burst on overpressure. Shots CHARLIE and DOG were also part of the SNAPPER phase, of primary concern to the AEC and the Los Alamos National Laboratory. The other weapons development tests in the SNAPPER phase were EASY, FOX, GEORGE, and HOW. The primary purpose of these four tower shots was to gather information on nuclear phenomena and to improve the design of nuclear weapons (9: 1).

4.7.2 TUMBLER-SNAPPER Test Operations.

About 7,350 of the estimated 8,700 DOD participants in Operation TUMBLER-SNAPPER took part in Exercise Desert Rock IV. The remaining DOD personnel assisted in scientific experiments, air support activities, or administrative and support activities at the NTS (9: 1).

Exercise Desert Rock IV, an Army training program involving personnel from the armed services, included observer programs at Shots CHARLIE, DOG, FOX, and GEORGE and tactical maneuvers after Shots CHARLIE, DOG, and GEORGE. The tactical maneuvers were designed in part to provide realistic training for ground units when supported by tactical atomic weapons and to determine the psychological reactions of troops participating in the exercise. The DOG tactical maneuver was the first Marine Corps maneuver of the CONUS tests. In addition to these activities, Exercise Desert Rock IV involved psychological tests at CHARLIE, FOX, and GEORGE to gauge the troops' reactions to witnessing a nuclear detonation (9: 1,5).

Figure 9 shows troops advancing into the test area behind a radiological safety monitor on 2 May 1952, 1 day after the detonation of DOG. The troops halted as the monitor took measurements with a Geiger Counter (B).

4.7.3 Dose Summary for Operation TUMBLER-SNAPPER.

A dose limit of 3.0 rem of gamma radiation per 13-week period was established for participants in Exercise Desert Rock IV, the joint AEC-DOD organization (coordinator of the series), and most of the Air Force Special Weapons Center (AFSWC) activities (9: 7). The following table presents the available dosimetry information:

Summary of External Doses for Operation TUMBLER-SNAPPER as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	3,848	467	61	17	6	1
Navy	446	45	61	4	0	0
Air Force	1,112	35	42	17	3	0
Marine Corps	2,033	8	1	0	0	0
Civilian DOD Participants	368	43	82	10	0	0

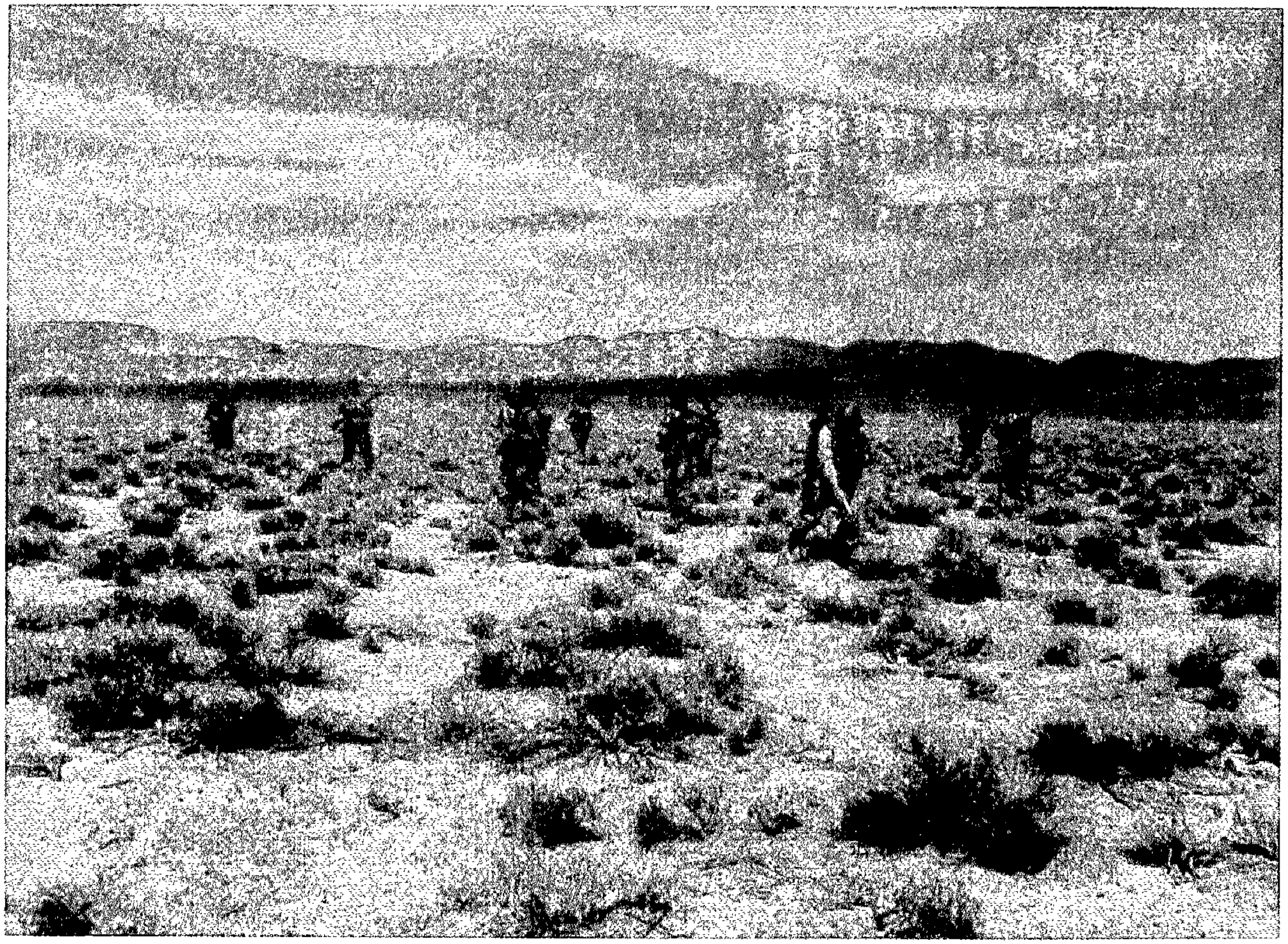


Figure 9. Troops advancing into the test area behind a radiological safety monitor on 2 May 1952, one day after the detonation of DOG.

4.8 OPERATION IVY.

IVY, conducted at Enewetak Atoll during autumn 1952, consisted of two detonations. These two detonations, identified in the following table, were the largest nuclear explosions up to that time:

Event	Date	Type	Yield
MIKE	1 November	Surface	10.4 megatons
KING	16 November	Airdrop	500 kilotons

The description of the MIKE detonation by the author of History--Task Group 132.1 and reproduced in History of Operation IVY bears repeating (10: 1,187):

> The Shot, as witnessed aboard the various vessels at sea, is not easily described. Accompanied by a brilliant light, the heat wave was felt immediately at distances of thirty to thirty-five miles. The tremendous fireball, appearing on the horizon like the sun when half-risen, quickly expanded after a momentary hover time and appeared to be approximately a mile in diameter before the cloud-chamber effect and scud clouds partially obscured it from view. A very large cloud-chamber effect was visible shortly after the detonation and a tremendous conventional mushroom-shaped cloud soon appeared, seemingly balanced on a wide dirty stem. Apparently, the dirty stem was due to the coral particles, debris, and water which were sucked high into the air. Around the base of the stem, there appeared to be a curtain of water which soon dropped back around the area where the island of Elugelab [Eluklab] had been.

Figure 10 presents a photograph of the MIKE cloud (C).

4.8.1 Background and Objectives of Operation IVY.

President Truman made the decision to pursue the development of thermonuclear weapons in 1950. Operation GREENHOUSE was an initial step toward this end, as section 4.5 explains. Operation IVY considerably extended the

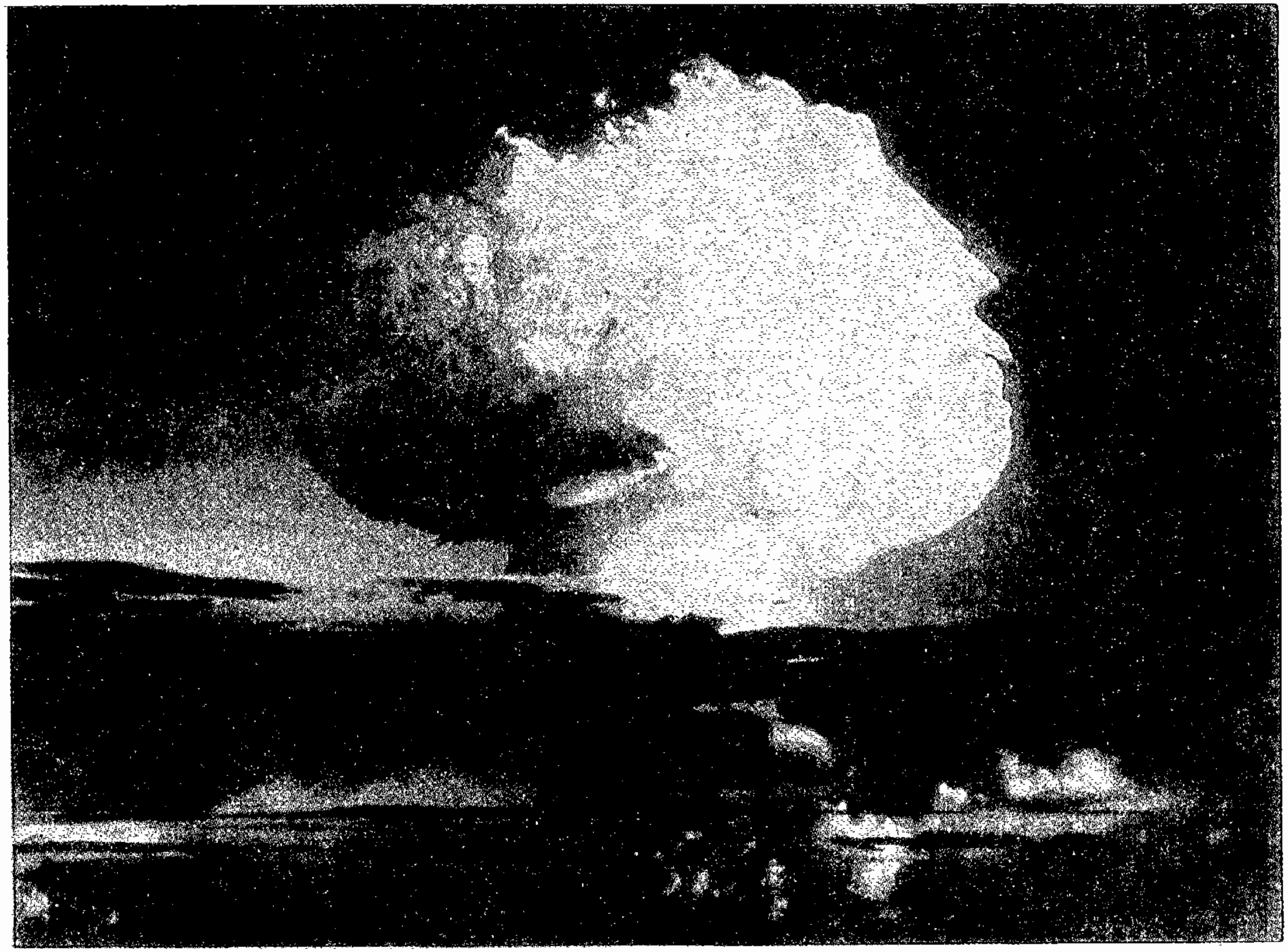


Figure 10. Shot MIKE, 1 November 1952.

GREENHOUSE advances. MIKE, an experimental device, produced the first thermonuclear detonation, which means that a substantial portion of its energy was generated by the fusion, or joining, of hydrogen and other light atoms. KING was a stockpile weapon, modified to produce a large yield. The energy from KING was generated by the fission, or splitting, of plutonium atoms (10: 1).

The IVY test program was the result not only of scientific and technical considerations, but also of an intense controversy within elements of the U.S. Government concerned with foreign policy and defense matters. During the early 1950s, various plans rapidly evolved to meet the challenge posed by the initial Soviet detonation, of 1949. Most plans called for increased development and production of fission weapons and the required delivery systems. One plan called for the development of fusion, or thermonuclear, weapons with vastly greater explosive power. Opponents of fusion weapons argued that the Soviets could be persuaded not to develop these weapons if the United States would refrain. A further argument, among others, was that such weapons were not much more effective than high-yield fission weapons (10: 18).

The advocates of fusion weapons prevailed, and MIKE became the centerpiece of Operation IVY and the proof-test of the new technology. KING, however, represented a test of the kind of high-yield fission weapon some of the fusion opponents had in mind. To a degree, the KING device also offered a backup to help ease the national sense of vulnerability in the event that the initial attempt at a fusion reaction detonation was unsuccessful (10: 18-19).

4.8.2 IVY Test Operations.

IVY engaged nearly 11,650 participants, of whom approximately 9,350 were military and about 2,300 were civilians. Most of the civilians and over 6,600 of the military personnel operated from Enewetak Atoll and from task force ships based there. These personnel were removed to evacuation ships before the detonation of MIKE. Most of the additional military were Air Force personnel who were based at Kwajalein, 350 nautical miles southeast of Enewetak (10: 2,178-181).

The experimental program for IVY focused primarily on the MIKE experiment and secondarily on KING. The effort, subdivided into 11 specific programs, was heavily oriented to weapons development experiments and focused to a lesser extent on effects experiments (10: 118).

4.8.3 Dose Summary for Operation IVY.

The generally smooth MIKE operations were marred by an accident when a cloud-sampling pilot was lost at sea after his aircraft ran out of fuel. A seven-man rescue crew flew their aircraft over a fallout zone to reach the area of the downed airplane as soon as possible. In the process, the crewmembers received radiation doses ranging from 10 to 17.8 rem. These levels considerably exceeded the maximum permissible limit of 3.9 rem of gamma radiation established for Operation IVY participants (10: 3).

A crew of 12 in a second aircraft was overexposed when caught in fallout debris while on a photographic mission just after the MIKE shot. The highest dose for a member of this crew was 11.6 rem. Other than these two events, no cases exceeded the established limit during IVY (10: 3).

Summary of External Doses for Operation IVY as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	1,300	1	1	0	0	0
Navy	5,191	23	42	2	0	0
Air Force	2,199	325	37	4	9	10
Marine Corps	169	1	8	0	0	0
Civilian DOD Participants	28	0	3	0	0	0

4.9 OPERATION UPSHOT-KNOTHOLE.

Conducted at the NTS from 17 March to 4 June 1953, Operation UPSHOT-KNOTHOLE consisted of 11 nuclear tests, a number exceeding that of any previous nuclear test series. The following table summarizes these shots:

Event	Date	Type	Yield (Kilotons)
ANNIE	17 March	Tower	16
NANCY	24 March	Tower	24
RUTH	31 March	Tower	0.2
DIXIE	6 April	Airdrop	11
RAY	11 April	Tower	0.2
BADGER	18 April	Tower	23
SIMON	25 April	Tower	43
ENCORE	8 May	Airdrop	27
HARRY	19 May	Tower	32
GRABLE	25 May	Airburst	15
CLIMAX	4 June	Airdrop	61

ANNIE, the first device tested, was an "open shot," meaning that reporters were allowed to view the detonation from News Nob, 11 kilometers south of the shot-tower. The Government wanted to show the American public that nuclear weapons could be used defensively, without destroying large urban centers and populations (11: 1,13,2,30,31).

The firing of GRABLE from a 280 mm cannon, shown in figure 11, marked the first time an atomic artillery shell was fired and detonated (D). The Secretary of Defense, the Secretary of the Army, and the Army Chief of Staff, along with 96 Congressional observers, viewed the detonation from an area 11 kilometers west of ground zero (12: 120).

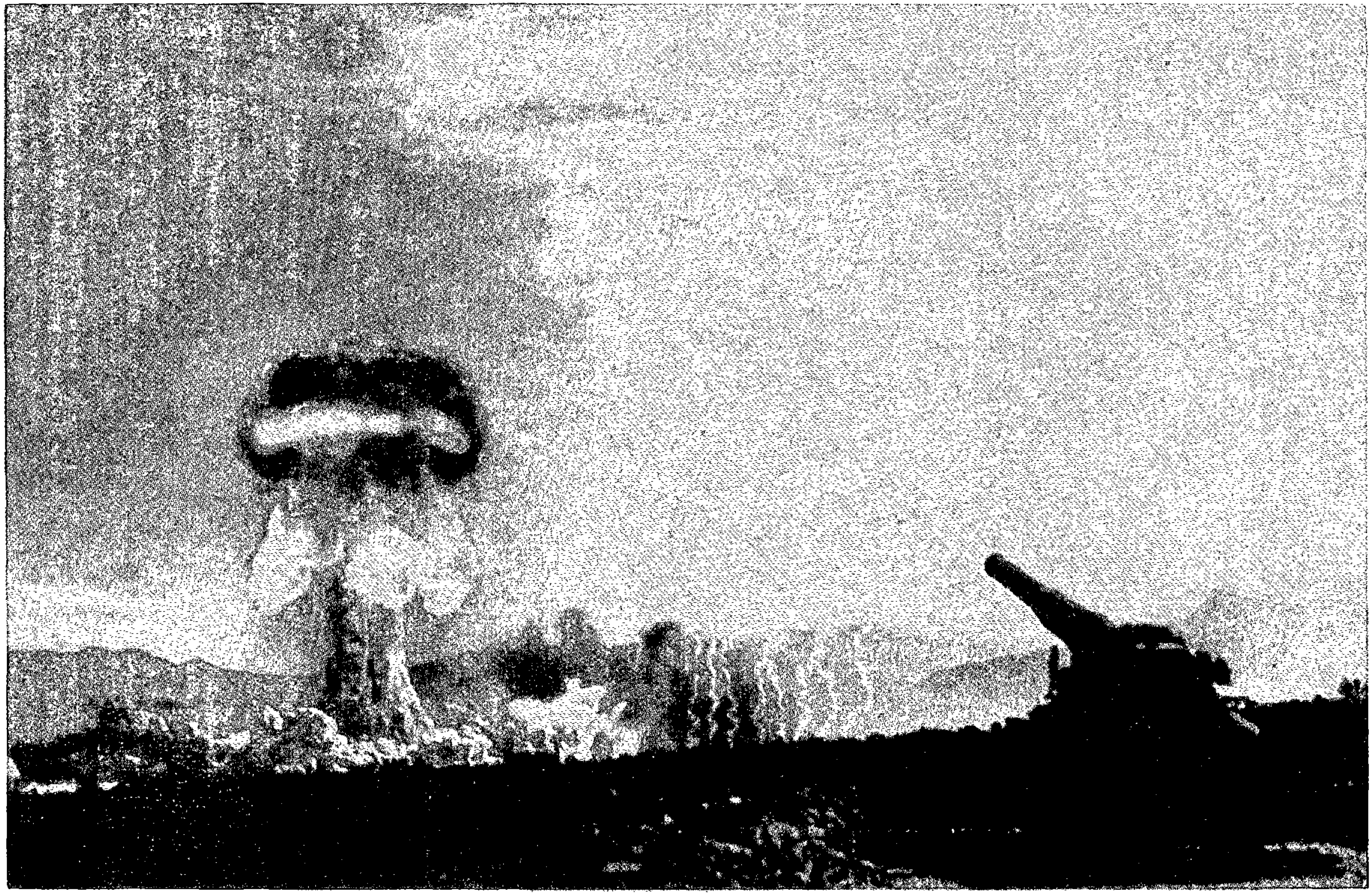


Figure 11. Shot GRABLE, only test of the 280mm atomic artillery shell, 25 May 1953.

4.9.1 Background and Objectives of Operation UPSHOT-KNOTHOLE.

UPSHOT-KNOTHOLE went a step further than the previous CONUS series, TUMBLER-SNAPPER, which had explored the use of nuclear weapons for tactical purposes. Designed to address both the tactical and strategic considerations of the U.S. defense policy, UPSHOT-KNOTHOLE was designed to accomplish the following (11: 33):

- Establish military doctrine for the tactical use of nuclear weapons
- Improve the nuclear weapons used for strategic bomber delivery and those used for tactical battlefield situations.

Like the earlier BUSTER-JANGLE and TUMBLER-SNAPPER series, UPSHOT-KNOTHOLE was initially envisioned as two separate weapons testing programs: Operation UPSHOT and Operation KNOTHOLE. Plans began in late 1951 for a large military effects test, later called Operation KNOTHOLE, to be conducted during the spring of 1953 at the NTS. The objective was to obtain general weapons effects information to supplement the data obtained from Operation GREENHOUSE, conducted at the Pacific during spring 1951 (11: 32).

Meanwhile, the AEC was planning Operation UPSHOT, with the earliest test date set for spring 1953. The DOD consequently accelerated its planning for Operation KNOTHOLE so that arrangements for the AEC and DOD tests could be coordinated. In June 1952, the DOD and AEC agreed to conduct the spring 1953 tests as a combined operation, designated UPSHOT-KNOTHOLE (11: 32).

4.9.2 UPSHOT-KNOTHOLE Test Operations.

An estimated 18,000 DOD personnel participated at UPSHOT-KNOTHOLE in observer programs, tactical maneuvers, scientific studies, and support activities. The largest DOD participation was in Exercise Desert Rock V, which involved members of all four armed services. Exercise Desert Rock V included troop orientation and training, a volunteer officer observer program, tactical troop maneuvers, operational helicopter tests, and damage effects evaluation. The troop orientation and training included briefings before the detonation on nuclear weapons characteristics and effects and on personal protection; figure 12 is a photograph of one such briefing (E). Troop orientation and training also involved observation of a nuclear detonation, as

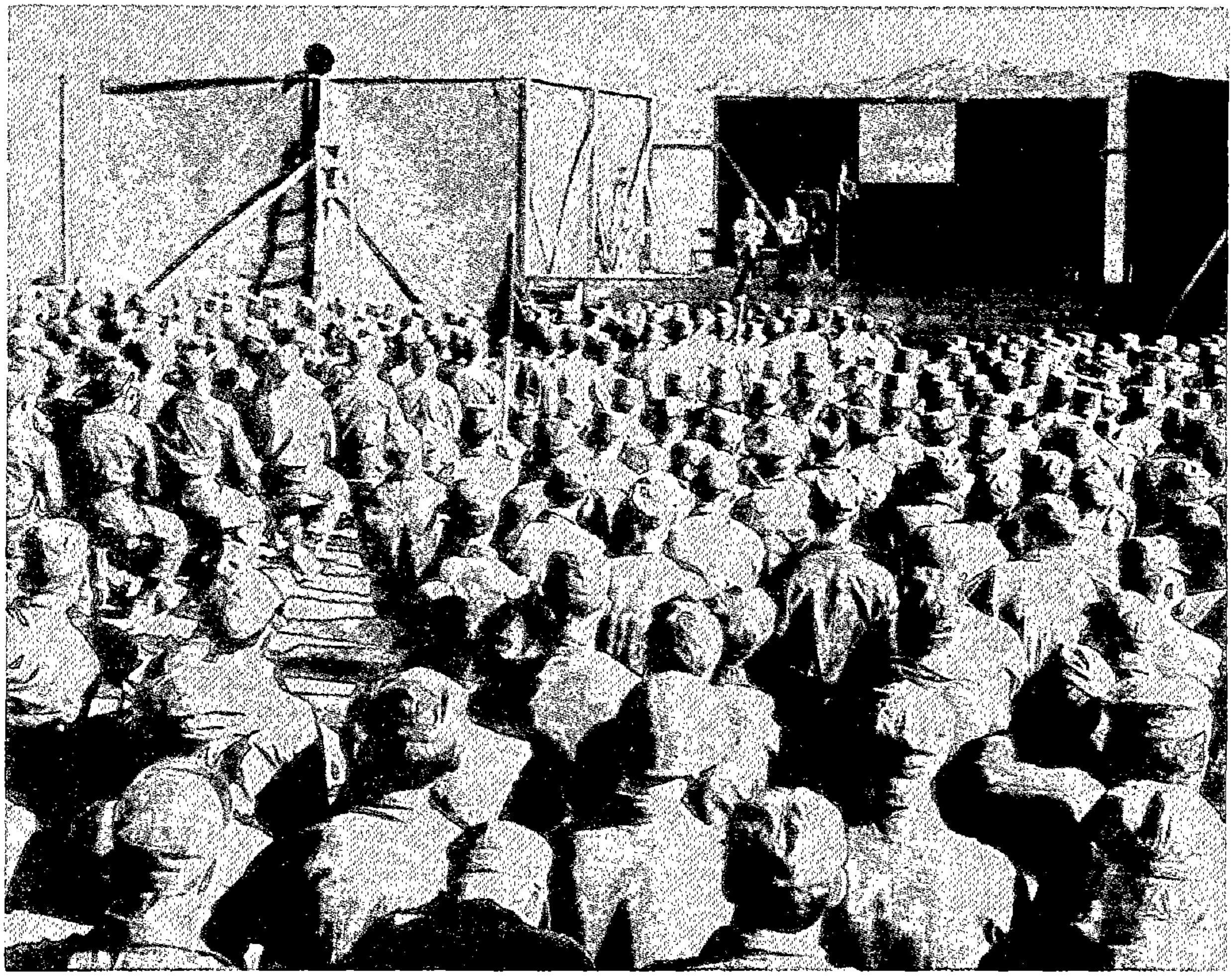


Figure 12. Exercise Desert Rock V troops being briefed on the characteristics and effects of nuclear detonations before the Operation UPSHOT-KNOTHOLE tests.

did the volunteer officer observer program. For the latter, trained staff officers calculated the effects of a nuclear detonation to determine a minimum safe distance for observing the blast; they later watched the detonation from the calculated position. Among the other activities, the operational helicopter tests performed by the Marine Corps were designed to investigate the capability of helicopters and their crews to withstand a nuclear burst and its effects (11: 1).

4.9.3 Dose Summary for Operation UPSHOT-KNOTHOLE.

The maximum permissible dose for participants in the Joint Test Organization, which coordinated UPSHOT-KNOTHOLE, and AFSWC was 3.9 rem of gamma radiation for the series. The limits were higher for Desert Rock V participants, according to the requirements of their missions. Desert Rock V troops were restricted to a maximum of 6.0 rem of gamma radiation for the series, with no more than 3.0 rem of prompt radiation. The volunteer officer observers were limited to 10.0 rem of gamma radiation, with no more than 5.0 rem of prompt radiation per test, and a total of no more than 25.0 rem for the exercise (11: 11).

Dosimetry information is available for the volunteer officer observers, who participated at Shots NANCY, BADGER, and SIMON. The exposures of seven of the eight SIMON observers exceeded the 10.0 rem shot limit, with a high of 17.5 rem. The one volunteer observer who witnessed all three shots had an exposure of 26.6 rem (11: 12).

The calculated mean neutron doses for the volunteer observers have been reconstructed as 0.63 rem for Shot NANCY; 2.4 rem for Shot BADGER; and 28 rem for Shot SIMON (11: 12,15).

Summary of External Doses for Operation UPSHOT-KNOTHOLE as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	3,705	3,041	4,459	1,299	20	10
Navy	402	171	96	87	16	1
Air Force	1,125	226	260	45	17	3
Marine Corps	112	205	330	1,611	16	1
Civilian DOD Participants	98	28	28	2	0	0

4.10 OPERATION CASTLE.

CASTLE was conducted at Enewetak and Bikini Atolls during the spring of 1954. The first event of this series, Shot BRAVO, had a yield of 15 megatons and was the largest device ever detonated by the U.S. Government as part of atmospheric nuclear weapons testing. The following table provides specifics on this detonation, shown in figure 13 (F), as well as the other five in the series (13: 1):

Event	Date	Type	Yield
BRAVO	1 March	Surface	15 megatons
ROMEO	27 March	Barge	11 megatons
KOON	7 April	Surface	110 kilotons
UNION	26 April	Barge	6.9 megatons
YANKEE	5 May	Barge	13.5 megatons
NECTAR	14 May	Barge	1.69 megatons

4.10.1 Background and Objectives of Operation CASTLE.

CASTLE was the culmination in the development of the super, or hydrogen, bomb that began in 1950. Shot GEORGE, a test in the 1951 GREENHOUSE series, had demonstrated the initiation of a sustained thermonuclear reaction by use of a fission reaction. Fusion, or thermonuclear, reactions had been used in

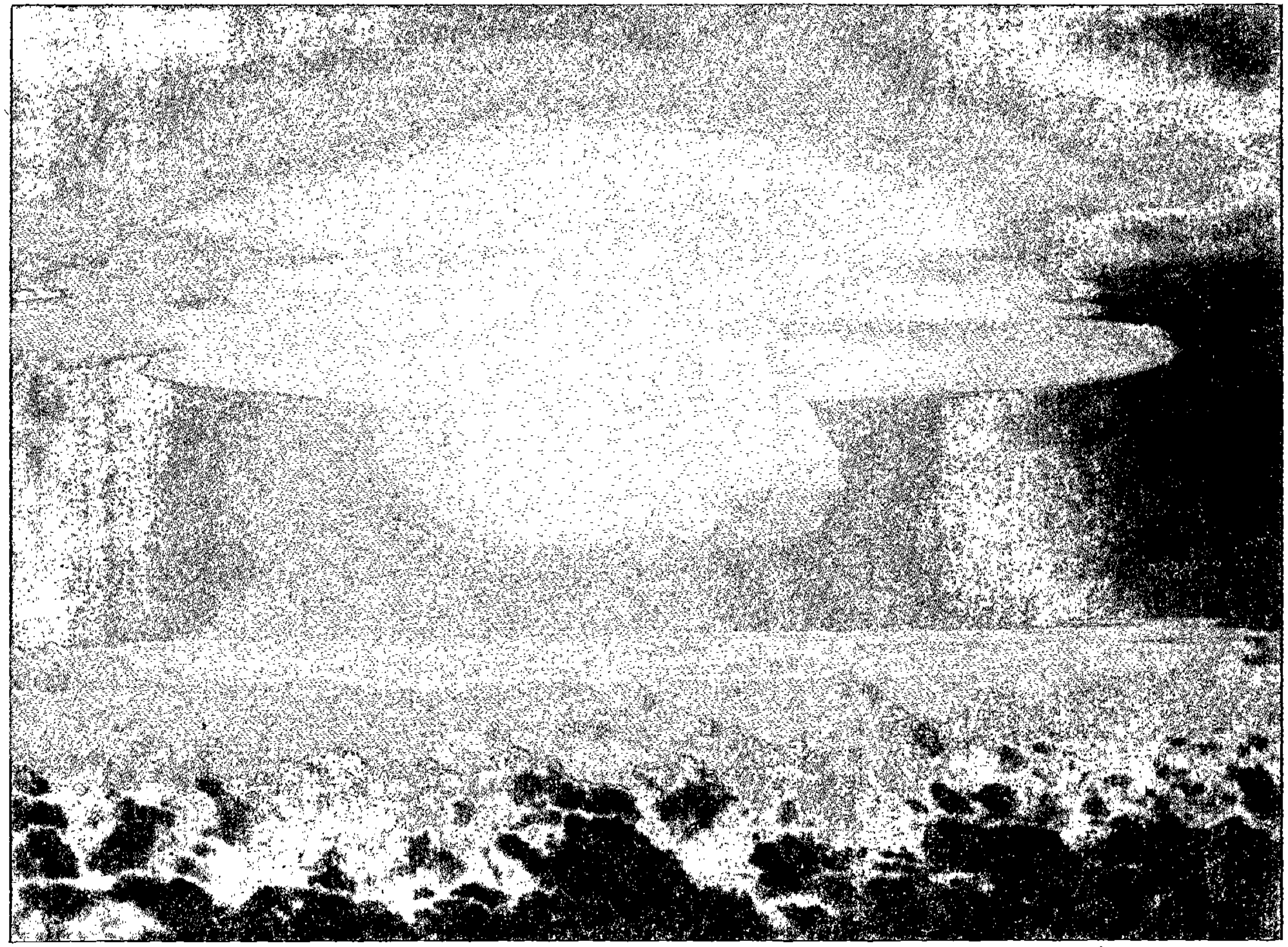


Figure 13. Shot BRAVO, 1 March 1954.

1952 to generate the very powerful detonation of the MIKE device in Operation IVY, but MIKE was not a deliverable nuclear weapon. In BRAVO, the first CASTLE test, a device more powerful than MIKE was exploded that, although not a weapon, was capable of delivery by an aircraft (13: 26).

CASTLE also was the first Pacific series in which the Lawrence Livermore National Laboratory (LLNL) provided a nuclear device for testing, detonated as Shot KOON. All previous nuclear test devices had been designed at the Los Alamos National Laboratory (13: 26).

4.10.2 CASTLE Test Operations.

Numerous technical experiments were carried out in conjunction with each of the six detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the explosions. The approximately 12,700 DOD participants in this series had duty stations at the AEC design laboratories or were members of units performing separate experiments or various support roles. Almost all of the Navy support personnel were at Bikini, where Navy ships provided living quarters for participants who were evacuated from the islands for the first test and then could not return to live there because of the potential radiation exposure (13: 2).

4.10.3 Dose Summary for Operation CASTLE.

Among the CASTLE detonations, only BRAVO produced significant, unexpected personnel radiation exposures. This first shot of the series, which significantly exceeded its expected yield, released large quantities of radioactive materials into the atmosphere. These materials were caught up in winds that spread the particles over a much larger area than had been anticipated. This resulted in contamination and exposure of Marshall Island residents, Japanese fishermen, and U.S. personnel on distant atolls or aboard various vessels. Acute radiation effects were observed among some of these people (13: 3).

Some DOD personnel exceeded the maximum permissible limit of 3.9 rem of gamma radiation within any 13-week period of the operation. BRAVO fallout on some Navy ships resulted in personnel who had doses approaching or exceeding this limit. To allow for completion of the CASTLE tests, it became necessary to issue a number of waiver authorizations permitting doses of as much as

7.8 rem. In a limited number of shipboard cases, even this level was exceeded. Substantial overdoses from BRAVO, the highest for any test series, were accrued by the 28 Air Force and Army personnel on Rongerik Atoll (13: 3-4) and the 92 crew members of USS Patapsco, a Navy gasoline tanker that was overtaken by the nuclear cloud on the day following the shot while enroute from Enewetak Atoll to Pearl Harbor (14). Film badge readings suggest that three members of the U.S. Navy Bikini Boat Pool also may have received substantial overdoses. Thorough investigation at the time failed, however, to indicate reasons for these readings (13: 243-244). As a result of BRAVO, 21 individuals on the USS Philip and 16 on the USS Bairoko sustained lesions that were classified as beta burns, all of which healed without complications (13: 3-4).

Summary of External Doses for Operation CASTLE as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	0	0	1,341	47	6	3
Navy	3,940	1,462	2,210	695	211	115
Air Force	984	193	970	62	30	31
Marine Corps	160	8	101	29	5	0
Civilian DOD Participants	30	6	13	0	0	0

4.11 OPERATION TEAPOT.

Conducted from 18 February to 15 May 1955, Operation TEAPOT was the fifth series of CONUS tests. Two of the 14 nuclear detonations in the series, APPLE 1 and WASP PRIME, occurred on the same day although in different parts of the NTS. ESS, the only TEAPOT subsurface detonation (-67 feet), forced tons of earth upward, thereby creating a crater 88 meters wide and 96 feet deep. Figure 14 shows Exercise Desert Rock VI troops observing the ESS detonation (G). They were positioned approximately 8 kilometers from the shot site.

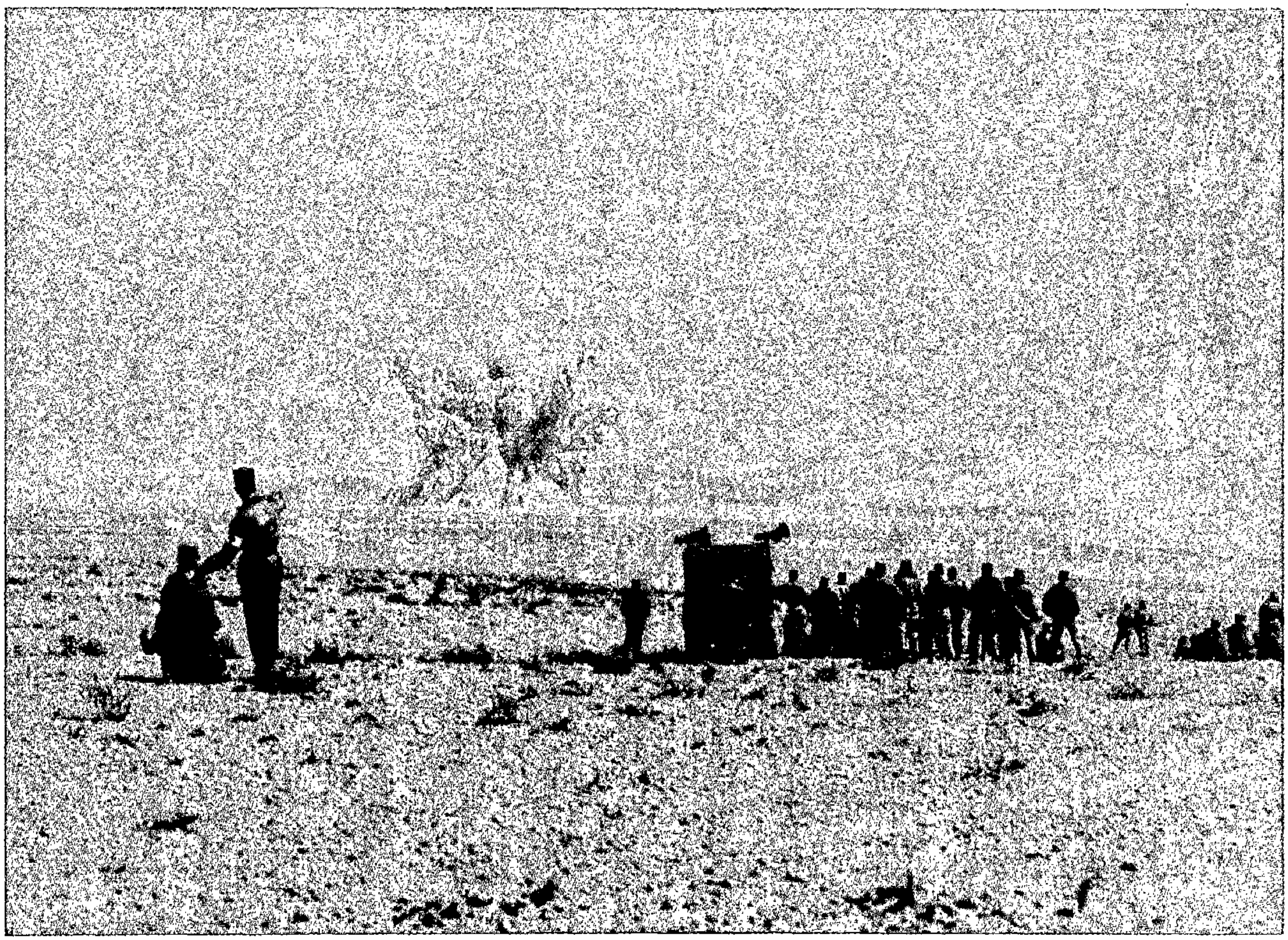


Figure 14. Exercise Desert Rock VI troops observing the detonation of ESS, 23 March 1955.

The TEAPOT schedule was continually revised as the AEC waited for appropriate weather conditions for firing the test shots. The delay in one shot often resulted in postponing subsequent shots, regardless of the weather. The many schedule changes, affecting all but the first two shots, caused a 6-week extension of TEAPOT from 1 April to 15 May (15: 29).

The following table provides data on the TEAPOT tests (15: 1,5,9):

Event	Date	Type	Yield (kilotons)
WASP	18 February	Airdrop	1
MOTH	22 February	Tower	2
TESLA	1 March	Tower	7
TURK	7 March	Tower	43
HORNET	12 March	Tower	4
BEE	22 March	Tower	8
ESS	23 March	Crater	1
APPLE 1	29 March	Tower	14
WASP PRIME	29 March	Airdrop	3
HA	6 April	Airdrop	3
POST	9 April	Tower	2
MET	15 April	Tower	22
APPLE 2	5 May	Tower	29
ZUCCHINI	15 May	Tower	28

4.11.1 Background and Objectives of Operation TEAPOT.

Operation TEAPOT furthered the efforts of the previous CONUS series, the 1953 Operation UPSHOT-KNOTHOLE, which had studied both the tactical and strategic uses of nuclear weapons (see section 4.9) (15: 27). Authorized by President Eisenhower on 30 August 1954, TEAPOT had two primary objectives:

- To establish military doctrine and tactics for the use of ground forces on a nuclear battlefield

- To improve the nuclear weapons used for strategic bomber delivery and missile delivery and those used for tactical battlefield situations.

The DOD conducted Exercise Desert Rock VI to achieve the first objective, and the AEC fielded scientific experiments to achieve the second (15: 27,28).

4.11.2 TEAPOT Test Operations.

Approximately 8,700 DOD personnel participated in TEAPOT observer programs, tactical maneuvers, scientific studies, and support activities. The largest number, about 8,000, took part in Exercise Desert Rock VI, which included observer programs at Shots WASP, MOTH, TESLA, TURK, BEE, ESS, APPLE 1, and APPLE 2 and troop tests at Shots BEE and APPLE 2. The largest single TEAPOT activity was the Marine Brigade Exercise at BEE, which involved about 300 officers and 1,950 enlisted men. The objective of the exercise was to train personnel and to test the tactics and techniques employed if a nuclear detonation were used to support an air-ground task force. The troop test at APPLE 2, involving about 1,000 troops, was designed to demonstrate the capability of a reinforced tank battalion to seize an objective immediately after a nuclear detonation. In addition to these activities, technical studies were conducted at 10 of the shots (15: 1,5-7).

4.11.3 Dose Summary for Operation TEAPOT.

The maximum dose limit for personnel of the Joint Test Organization, which coordinated Operation TEAPOT, and AFSWC was 3.9 rem of gamma radiation during the series. The limit for Desert Rock troops was 6.0 rem of gamma radiation during the series, with no more than 3.0 rem of prompt radiation. The Desert Rock troops had this higher limit because they, unlike JTO and some AFSWC technical personnel, were not likely to be exposed to radiation after the tests (15: 2,3).

The 10 Desert Rock volunteer officer observers at APPLE 2 were authorized a special limit of 10.0 rem of gamma radiation. Their average film badge readings were 1.3 rem. Pilots for Project 2.8b, Manned Penetrations of Atomic Clouds, were authorized a limit of 15 rem. One participant had a film badge reading of 21.7 rem, and another received 21.8 rem (15: 3).

Summary of External Doses for Operation TEAPOT as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	2,280	1,088	1,234	51	5	0
Navy	287	32	197	21	0	4
Air Force	842	73	103	55	5	4
Marine Corps	462	1,450	4	0	0	0
Civilian DOD Participants	128	3	1	0	0	0

4.12 OPERATION WIGWAM.

Operation WIGWAM consisted of only one nuclear detonation, a deep underwater test conducted in the Pacific Ocean approximately 500 miles southwest of San Diego, California. The device was suspended by cable from an unmanned barge and detonated at a depth of 2,000 feet in water 16,000 feet deep. The test, which had a yield of 30 kilotons, occurred on 14 May 1955 at 1300 hours Pacific Daylight Time (16: 9).

The test site was chosen after careful deliberation. AT DOD request, Scripps Institution of Oceanography surveyed various locations in the Pacific, the Caribbean, and the Atlantic. The site had to be deep enough to contain the detonation, yet away from undersea or sea bottom perturbations, such as sea mounts, ridges, and islands. Migratory fishing areas were to be avoided. In addition, the site was to have fairly well-known currents and thermal gradients, a predominance of good weather, and isolation from shipping lanes. The area selected was judged the best to fulfill the requirements (16: 1-11).

4.12.1 Background and Objectives of Operation WIGWAM.

Prior to WIGWAM, nuclear weapons had been tested in the atmosphere, on the surface of the earth or water, or at a shallow underwater depth. Considerable interest developed, particularly within the Navy, in investigating deep underwater effects by detonating a weapon at sufficient depth to contain all the initial energy of the nuclear explosion in the water (16: 1-3).

The Navy needed to know how a deep underwater shot would affect naval forces and, specifically, the answers to two leading questions: (1) What are the characteristics and lethal ranges of the resulting underwater shock wave? and (2) What are the effects of the radioactivity, following the explosion, on naval tactical operations? For example, could a surface vessel use a nuclear depth charge to destroy submerged enemy submarines without endangering itself? Specific answers to these questions were required to plan possible naval use of these weapons (16: 1-3,1-5).

4.12.2 WIGWAM Test Operations.

Approximately 6,800 personnel and 30 ships participated in Operation WIGWAM. They conducted or supported the three scientific programs designed to collect the desired data (16: 9,1-3).

A 6-mile towline connected the fleet tug, USS Tawasa, and the barge from which the nuclear device was suspended. Located at varying distances along this towline were a variety of pressure-measuring instruments, unmanned and specially prepared submerged submarine-like hulls (called squaws), as well as instrumented and also unmanned surface boats (16: 9).

The ships and personnel conducting the test were positioned 5 miles upwind from the barge that suspended the nuclear device. The only exceptions were for USS George Eastman (YAG-39) and USS Granville S. Hall (YAG-40). These two extensively reconfigured ships, equipped with special shielding to prevent radiological exposure, were stationed 5 miles downwind from the barge. Recovery parties later reentered the test area with radiological safety monitors, and after aerial surveys showed the general location and size of the contaminated water area and the radiation levels (16: 9).

4.12.3 Dose Summary for Operation WIGWAM.

The maximum dose limit for WIGWAM was 3.9 rem of gamma radiation for the duration of the operation. The two vessels (YAG-39 and YAG-40) stationed downwind of the detonation were subjected to contamination by water droplets of the base surge. Because of the special shielding, however, none of the YAG personnel exceeded the radiation limit. All doses were low because most of the radioactivity was confined deep under the surface of the water (16: 10,11).

WIGWAM was the first series in which nearly all participants were issued film badges. Personnel whose duties were such that exposure to radiation was possible (such as sampling radioactive water, recovering equipment or instruments) were issued additional film badges on a daily basis. One of the vessels, the USS Wright, contained a film processing center where badges were read and personnel exposures were recorded. Over the period of the operation, approximately 10,000 film badges were issued (16: 10).

Summary of External Doses for Operation WIGWAM as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	9	0	0	0	0	0
Navy	6,567	1	0	0	0	0
Air Force	64	0	0	0	0	0
Marine Corps	109	0	1	0	0	0
Civilian DOD Participants	17	0	1	0	0	0

4.13 OPERATION REDWING.

REDWING was conducted in 1956 as the sixth nuclear test series at the Marshall Islands, specifically at Enewetak and Bikini Atolls. The series consisted of the 17 detonations identified in the accompanying table. Figure 15 presents a photograph taken during the ERIE detonation, the fifth shot of

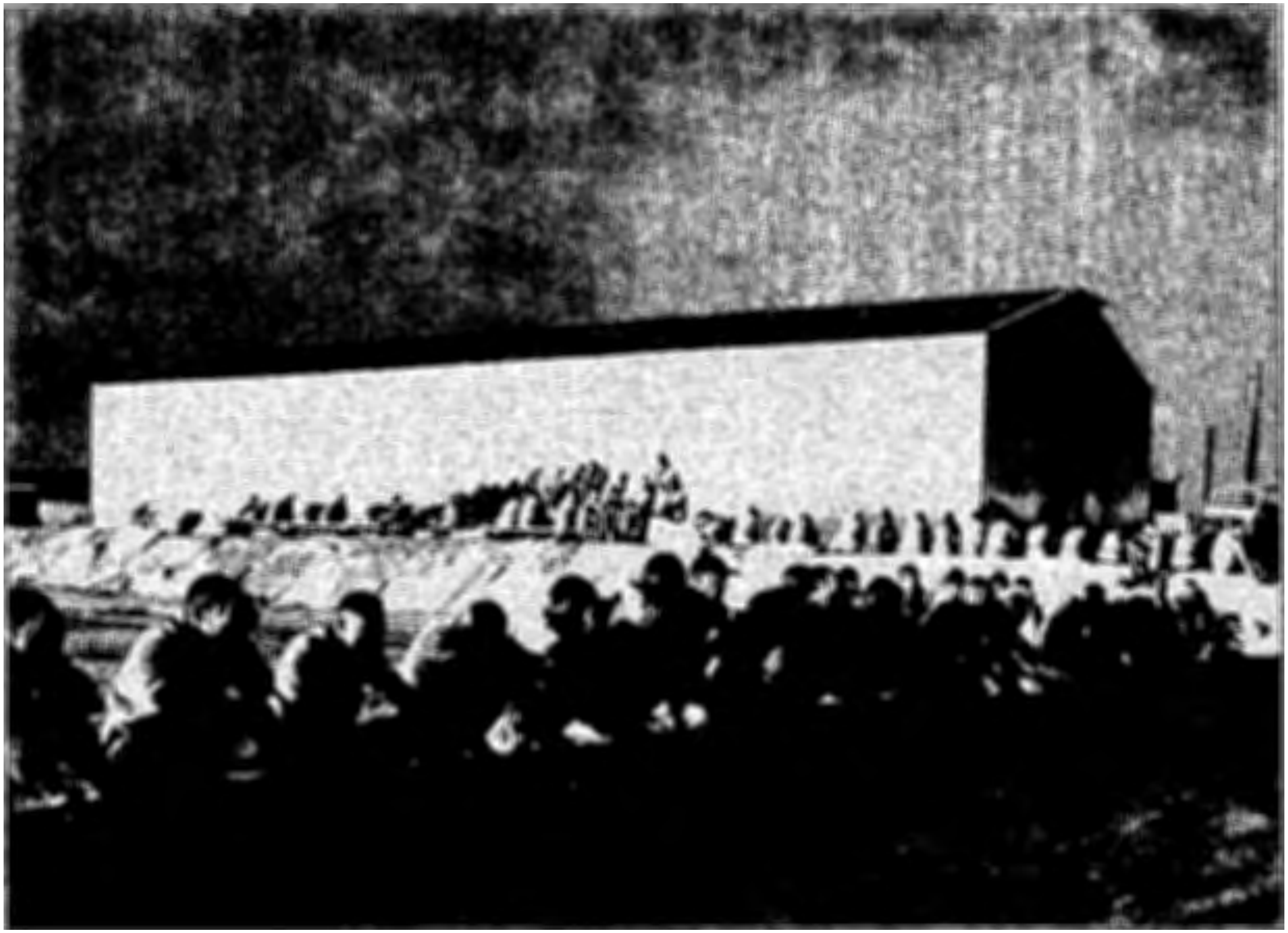


Figure 15. Observers facing away from the detonation of ERIE, 31 May 1956.

the series. It shows a group on Enewetak turned away from the detonation as it breaks the predawn darkness (H).

Operation REDWING Test Events, 1956

Event	Date	Type	Yield
LACROSSE	5 May	Surface	40 kilotons
CHEROKEE	21 May	Airdrop	Several megatons
ZUNI	28 May	Surface	3.5 megatons
YUMA	28 May	Tower	NA*
ERIE	31 May	Tower	NA
SEMINOLE	6 June	Surface	13.7 kilotons
FLATHEAD	12 June	Barge	NA
BLACKFOOT	12 June	Tower	NA
KICKAPOO	14 June	Tower	NA
OSAGE	16 June	Airdrop	NA
INCA	22 June	Tower	NA
DAKOTA	26 June	Barge	NA
MOHAWK	3 July	Tower	NA
APACHE	9 July	Barge	NA
NAVAJO	11 July	Barge	NA
TEWA	21 July	Barge	5 megatons
HURON	22 July	Barge	NA

*Not announced

4.13.1 Background and Objectives of Operation REDWING.

The main purpose of Operation REDWING was to test high-yield thermonuclear devices that could not be tested in Nevada. The only shot of the series not expressly for weapons development was CHEROKEE, which was airdropped from a B-52. Its primary purpose was to demonstrate the ability of the U.S. to deliver large-yield nuclear devices. The event was viewed by 15 press observers, the first such group invited to view a Pacific nuclear test since the CROSSROADS deonations of 1946. Seventeen invited civil defense officials also observed the shot (17: 2, 177, 22-23).

During CASTLE, the fifth nuclear test series conducted in the Marshall Islands, a serious fallout contamination incident from Shot BRAVO had affected not only U.S. personnel but Marshall Island residents and Japanese fishermen as well. On 27 April, 8 days before the first REDWING detonation, a joint DOD-AEC press release identified the safety precautions in effect for the series. It described the improved fallout prediction capability available and the extensive monitoring that was to be done both at the Pacific Proving Ground and beyond. It also described programs for surveying marine life in the Pacific. Moreover, the release stated that the yields of the devices to be tested were expected to be lower than the largest of those detonated as part of Operation CASTLE (17: 21,22).

Press observers were invited to view part of the series. Fifteen members of the press, the first to observe oceanic tests since the CROSSROADS detonations of 1946, accordingly witnessed LACROSSE and CHEROKEE. Seventeen invited civil defense officials also observed the shots (17: 22).

4.13.2 REDWING Test Operations.

Numerous technical experiments were carried out in conjunction with each of the 17 detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the explosions. Approximately 11,350 DOD personnel took part in or supported these activities. Also present at the tests were several thousand personnel from the AEC and its contractors, a few from other Government agencies, and some foreign observers as well (17: 2).

Most of the Navy and Marine Corps personnel were on ships operating around Bikini providing supply, evacuation capability, and other support to the tests there. Most of the Army and Air Force personnel were on Enewetak. All the services had personnel assigned to laboratory organizations whose operations were conducted on both atolls as well as other locations in the Pacific (17: 3).

4.13.3 Dose Summary for Operation REDWING.

TEWA, the last REDWING event fired at Bikini, led to an increase in personnel doses. The edge of the TEWA cloud passed over Enewetak causing fallout on the Enewetak base camp. Because the incident occurred toward the end of the series, some personnel had already returned to the U.S. (17: 3,4). The remaining Enewetak personnel, however, received additional doses calculated at 2.0 to 3.3 rem from this incident (17: 3,4).

The personnel limit was 3.9 rem of gamma radiation for the series. The highest doses were received by Air Force flight officers whose missions required them to penetrate the clouds resulting from the nuclear detonations (17: 3,4).

Summary of External Doses for Operation REDWING as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	89	262	308	649	144	0
Navy	2,987	1,843	1,581	225	18	0
Air Force	769	289	938	717	86	12
Marine Corps	59	67	118	9	0	0
Civilian DOD Participants	62	5	38	1	0	0

4.14 OPERATION PLUMBBOB.

Conducted at the Nevada Test Site from 28 May to 7 October 1957, Operation PLUMBBOB included the 24 nuclear detonations summarized in the accompanying table. The series also included six safety experiments, conducted to ensure that no nuclear reaction would occur if the high explosive components of the device were accidentally detonated during storage or transport (18: 1,6,7). These tests are discussed with the subsequent safety experiments in section 4.18.

Operation PLUMBBOB Weapon-Related Events, 1957

Event	Date	Type	Yield
BOLTZMANN	28 May	Tower	12 kilotons
FRANKLIN	2 June	Tower	140 tons
LASSEN	5 June	Balloon	0.5 tons
WILSON	18 June	Balloon	10 kilotons
PRISCILLA	24 June	Balloon	37 kilotons
HOOD	5 July	Balloon	74 kilotons
DIABLO	15 July	Tower	17 kilotons
JOHN	19 July	Air to air missile	about 2 kilotons
KEPLER	24 July	Tower	10 kilotons
OWENS	25 July	Balloon	9.7 kilotons
STOKES	7 August	Balloon	19 kilotons
SHASTA	18 August	Tower	17 kilotons
DOPPLER	23 August	Balloon	11 kilotons
FRANKLIN PRIME	30 August	Balloon	4.7 kilotons
SMOKY	31 August	Tower	44 kilotons
GALILEO	2 September	Tower	11 kilotons
WHEELER	6 September	Balloon	197 tons
LAPLACE	8 September	Balloon	1 kilotons
FIZEAU	14 September	Tower	11 kilotons
NEWTON	16 September	Balloon	12 kilotons
RAINIER	19 September	Tunnel	1.7 kilotons
WHITNEY	23 September	Tower	19 kilotons
CHARLESTON	28 September	Balloon	12 kilotons
MORGAN	7 October	Balloon	8 kilotons

4.14.1 Background and Objectives of Operation PLUMBBOB.

Largely a joint AEC/DOD effort, Operation PLUMBBOB was planned as an integral part of the continuing U.S. program for developing the means to conduct nuclear warfare in defense of the Nation. The AEC wanted to test a number of nuclear devices scheduled for early production for the defense stockpile or those important to the design of improved weapons. The DOD used the series to continue its study of military weapons effects and, with Exercises Desert Rock VII and VIII, its training of personnel in nuclear operations (18: 34).

4.14.2 PLUMBBOB Test Operations.

About 13,300 DOD personnel participated in observer programs, tactical maneuvers, and scientific and diagnostic studies during Operation PLUMBBOB. Exercises Desert Rock VII and VIII, consisting of training programs, tactical maneuvers, and technical service projects, engaged the largest DOD participation. At Shot HOOD, approximately 2,150 Marines took part in a maneuver involving the use of a helicopter airlift and tactical air support. An estimated 1,144 Army troops (Task Force WARRIOR) participated in an airlift assault at Shot SMOKY, and about 110 Army troops (Task Force BIG BANG) were interviewed at Shot GALILEO to determine their psychological reaction to witnessing a detonation (18: 1,4,5).

4.14.3 Dose Summary for Operation PLUMBBOB.

The maximum dose limit for Desert Rock troops was 5.0 rem of gamma radiation in any 6-month period, with no more than 2.0 rem to be from prompt radiation. Participants in activities of the AEC Nevada Test Organization and AFSWC were limited to 3.0 rem for any 13-week period and 5.0 rem for one calendar year (18: 2,3).

Summary of External Doses for Operation PLUMBBOB as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	6,242	737	528	55	22	2
Navy	401	36	130	4	2	1
Air Force	1,678	118	102	22	18	4
Marine Corps	726	1,244	176	1	1	0
Civilian DOD Participants	819	22	22	0	0	0

4.15 OPERATION HARDTACK I.

HARDTACK was the designation for U.S. nuclear testing in both the Pacific and in Nevada during 1958. Phase I, discussed in this section, consisted of 34 Pacific nuclear detonations, which was as many as had been fired in all prior oceanic tests. The series encompassed a wide variety of events, as indicated in the accompanying table (19: 23,24).

All but two of the detonations were at Enewetak and Bikini Atolls in the Marshall Islands. TEAK and ORANGE, high-altitude detonations, occurred 42 and 76 kilometers over Johnston Island, which lies about 700 nautical miles west-southwest of the Hawaiian Islands. A Honolulu resident described the TEAK burst, which took place 10 minutes before midnight, in a front-page story for the 1 August Honolulu Star-Bulletin (19: 1,266):

> I stepped out on the lanai and saw what must have been the reflection of the fireball. It turned from light yellow to dark yellow and from orange to red.
>
> The red spread in a semi-circular manner until it seemed to engulf a large part of the horizon.
>
> A cloud rose in the center of the circle. It was quite large and clearly visible. It remained visible for about a half hour.

It looked much closer than Johnston Island. The elevation of the circle was perhaps 20° above the horizon.

Operation HARDTACK I Nuclear Events, 1958

Event	Date	Type	Yield
YUCCA	28 April	High Altitude (Balloon)	NA*
CACTUS	6 May	Surface	18 kilotons
FIR	12 May	Barge	NA
BUTTERNUT	12 May	Barge	NA
KOA	13 May	Surface	1.37 megatons
WAHOO	16 May	Underwater	NA
HOLLY	21 May	Barge	NA
NUTMEG	22 May	Barge	NA
YELLOWWOOD	26 May	Barge	NA
MAGNOLIA	27 May	Barge	NA
TOBACCO	30 May	Barge	NA
SYCAMORE	31 May	Barge	NA
ROSE	3 June	Barge	NA
UMBRELLA	9 June	Underwater	NA
MAPLE	11 June	Barge	NA
ASPEN	15 June	Barge	NA
WALNUT	15 June	Barge	NA
LINDEN	18 June	Barge	NA
REDWOOD	28 June	Barge	NA
ELDER	28 June	Barge	NA
OAK	29 June	Barge	8.9 megatons
HICKORY	29 June	Barge	NA
SEQUOIA	2 July	Barge	NA
CEDAR	3 July	Barge	NA
DOGWOOD	6 July	Barge	NA

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*Not announced

Operation HARDTACK I Nuclear Events, 1958 (Continued)

Event	Date	Type	Yield
POPLAR	12 July	Barge	NA
PISONIA	18 July	Barge	NA
JUNIPER	22 July	Barge	NA
OLIVE	23 July	Barge	NA
PINE	27 July	Barge	NA
TEAK	31 July	High Altitude (Rocket)	megaton range
QUINCE	6 August	Surface	NA
ORANGE	11 August	High Altitude (Rocket)	megaton range
FIG	18 August	Surface	NA

4.15.1 Background and Objectives of Operation HARDTACK I.

HARDTACK I consisted of three parts. The first, aimed at the development of nuclear weapons, continued the type of testing that had been conducted at Enewetak and Bikini during the early and mid-1950s. The AEC weapon development laboratories (LANL and LLNL) detonated experimental devices, with the DOD providing support and conducting experiments that did not interfere with AEC activities (19: 1).

The second part, sponsored by DOD, consisted of the underwater test shots, WAHOO and UMBRELLA, the first in open ocean and the second within the lagoon at Enewetak. These tests, which furthered efforts undertaken with the 1946 CROSSROADS and the 1955 WIGWAM series, were designed to gain additional data on the effects of underwater explosions on Navy ships and material (19: 1).

The third part, sponsored by DOD, addressed a military problem that was newer: nuclear weapons in air and ballistic missile defense. Shots YUCCA, TEAK, and ORANGE, also called Operation NEWSREEL by DOD, were directed to this concern (19: 3).

4.15.2 HARDTACK I Test Operations.

The HARDTACK experimental program incorporated two aspects, one being the development of the weapons and the second being the measurement of the explosive and radiation effects. The AEC was primarily interested in weapons development, and the DOD focused on weapons effects, specifically concerning the military application of the weapons (19: 3).

Approximately 16,000 DOD personnel took part in HARDTACK I. They participated in the weapons development experiments by providing cloud-sampling aircraft and crews, along with ship patrols, instrument placement and recovery, and radioactive sample return. Their primary participation, however, was in the effects experiments associated with the underwater and the high-altitude shots (19: 105).

4.15.3 Dose Summary for Operation HARDTACK I.

The maximum permissible dose for HARDTACK I personnel was 3.75 rem of gamma radiation per consecutive 13-week period, with a maximum of 5.0 rem for the operation. The crew of air-sampling aircraft were authorized a special limit of 10.0 rem. In case of operational error or emergency, an additional dose of 10.0 rem would be accepted (19: 3,4).

During the series, one incident involved the exposure of participants to significantly elevated radiation levels. On 14 May, the base islands of Enewetak and Parry at Enewetak Atoll received fallout from a test shot detonated at Bikini 2 days earlier (19: 4,5). According to current calculations, the period of fallout, which lasted about 60 hours, could have contributed as much as 1.7 rem through 31 May 1958, 2.2 rem through 30 June 1958, and 2.5 rem through 31 July 1958 to personnel on the Enewetak Atoll.

Summary of External Doses for Operation HARDTACK I as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	249	258	1,011	54	2	0
Navy	5,307	2,746	1,656	26	1	0
Air Force	1,561	474	1,825	183	73	7
Marine Corps	60	99	56	4	0	0
Civilian DOD Participants	65	34	66	3	0	0

4.16 OPERATION ARGUS.

ARGUS, the code name for the only atmospheric nuclear test operation in the Atlantic Ocean, consisted of the three high-altitude, low-yield detonations identified below. The nuclear devices were lifted to about a 300-mile altitude by rockets fired from the missile trials ship USS Norton Sound (AVM-1), one of the nine ships participating in the series (20: 1).

The operation was based in the Atlantic at about 45° south latitude. The location placed the task force outside regular shipping lanes but kept the launch well within the range of U.S. military forces required for support of ARGUS scientific projects (20: 19).

Event	Date	Type	Yield (kilotons)
ARGUS I	27 August	Rocket	1-2
ARGUS II	30 August	Rocket	1-2
ARGUS III	6 September	Rocket	1-2

4.16.1 Background and Objectives of Operation ARGUS.

ARGUS was unique among U.S. atmospheric nuclear test operations in a number of respects. It was one of the most expeditiously planned and executed of all U.S. nuclear tests, requiring just 5 months from inception to execution, in contrast to the normal period of 1 or more years. Besides TRINITY, it consisted of the only clandestine tests conducted during the 18-year period of atmospheric testing. The intentions of all phases of the ARGUS operation were concealed not only from other nations but also from the majority of DOD participants in the tests. In addition, ARGUS was the first shipboard launch of a ballistic missile with a nuclear warhead (20: 11, 18).

Most significant of all, the purpose of ARGUS did not fit the usual categories: the ARGUS shots, strictly speaking, involved neither diagnostic tests of a weapon design nor effects tests on military systems. The objective was to establish the practicability of a theory, postulated by Nicholas Christofilos, a physicist at LLNL, that a very-high-altitude nuclear detonation of proper yield would produce phenomena of potentially significant military importance by interfering with communications and weapon performance. When the Eisenhower Administration officially announced the occurrence of the tests on 19 March 1959, the New York Times headlined ARGUS as the "Greatest Scientific Experiment Ever Conducted" (20: 11,12).

The operation proved the validity of the Christofilos theory. It not only provided data on military considerations, but also produced a great mass of geophysical information (20: 2).

4.16.2 ARGUS Test Operations.

The series was conducted by Task Force 88, a naval organization consisting of nine ships and approximately 4,500 men. Coordinated measurement programs using satellite, rocket, aircraft, and surface stations were carried out by the services and other Government agencies and contractors throughout the world. The ships of Task Force 88, in addition to the USS Norton Sound, were the antisubmarine carrier USS Tarawa, the destroyers USS Bearss and USS

Warrington, the destroyer escorts USS Courtney and USS Hammerberg, the fleet oilers USS Neosho and USS Salamonie, and the seaplane tender USS Albemarle (20: 1).

4.16.3 Dose Summary for Operation ARGUS.

The detonations occurred at such distances above the earth that the possibilities of personnel exposures to ionizing radiation were considered remote. The recorded doses were, in fact, so low as to be negligible. The highest level recorded by the 264 film badges distributed to the task force was 0.010 rem. The highest level recorded, 0.025 rem, was by a control film badge, which was not issued to personnel but remained in storage in a radiation-free area within a ship. Another control badge read 0.020 rem. These readings were so low that they probably were spurious and the result of environmental effects on film emulsions (20: 1,2).

4.17 OPERATION HARDTACK II.

HARDTACK II was the continental phase of Operation HARDTACK. The oceanic phase, HARDTACK I, was conducted in the Pacific from 28 April through 18 August 1958, as noted in section 4.15. Phase II, conducted at the Nevada Test Site from 12 September through 31 October 1958, consisted of 19 nuclear weapons tests and 18 safety experiments (21: 1). The next section, 4.18, discusses the safety experiments. This section concentrates on the weapons-related tests, identified in the accompanying table.

Operation HARDTACK II Nuclear Events, 1958

Event	Date	Type	Yield (kilotons)
EDDY	19 September	Balloon	0.083
MORA	29 September	Balloon	2
TAMALPAIS	8 October	Tunnel	0.072
QUAY	10 October	Tower	0.079
LEA	13 October	Balloon	1.4
HAMILTON	15 October	Tower	0.0012

Operation HARDTACK II Nuclear Events, 1958 (Continued)

Event	Date	Type	Yield (kilotons)
LOGAN	16 October	Tunnel	5
DONA ANA	16 October	Balloon	0.037
RIO ARRIBA	18 October	Tower	0.090
SOCORRO	22 October	Balloon	6
WRANGELL	22 October	Balloon	0.115
RUSHMORE	22 October	Balloon	0.188
SANFORD	26 October	Balloon	4.9
DE BACA	26 October	Balloon	2.2
EVANS	29 October	Tunnel	0.055
MAZAMA	29 October	Tower	NMY*
HUMBOLDT	29 October	Tower	0.0078
SANTA FE	30 October	Balloon	1.3
BLANCA	30 October	Tunnel	22

*No measurable yield

4.17.1 Background and Objectives of Operation HARDTACK II.

HARDTACK II was the last nuclear test series before the United States adopted a nuclear test moratorium, which had originally been intended to last 1 year but continued until 1961. The nuclear weapons tests were conducted to evaluate the yield and efficiency of newly developed nuclear devices (21: 1,7).

Concern about nuclear weapon proliferation intensified throughout the 1950s, particularly after the BRAVO test of Operation CASTLE and the heavy fallout resulting from this shot. At that time, Prime Minister Nehru of India proposed a cessation of tests. The call for a test ban figured repeatedly in disarmament discussions, most importantly, those of the Disarmament Subcommittee of the U.N. Disarmament Commission, in session from 18 March to 6 September 1957. Continuing pressure on the nuclear powers to reach an agreement on limiting testing resulted in the Conference on

Discontinuance of Nuclear Weapons Tests, which began in Geneva on 31 October 1958 and was attended by U.S., British, and Soviet delegates. On 1 November 1958, the U.S. unilaterally announced a test moratorium to begin on 1 November 1958, declaring a cessation in nuclear testing if the Soviet Union also refrained (21: 28).

Because the testing and improvement of various nuclear weapons was crucial to American defense policy, a number of tests needed to be conducted before the moratorium began. On 28 August 1958, President Eisenhower approved an accelerated series of nuclear tests code named Operation MILLRACE to be completed at the NTS before the start of the moratorium. On 29 August 1958, by AEC directive, the name of the series was changed to Operation HARDTACK, Phase II (21: 28,29).

4.17.2 HARDTACK II Test Operations.

An estimated 1,650 DOD personnel took part in HARDTACK II. This participation was relatively small compared with previous nuclear weapons testing series because of the weapons development emphasis of the program and because of the substantial DOD involvement (about 16,000 personnel) in HARDTACK I. The primary DOD involvement in HARDTACK II was at Shots HAMILTON and HUMBOLDT, the two weapons effects tests cosponsored by the DOD and the Lawrence Livermore National Laboratory. Projects at these tests were planned to develop delivery systems for small nuclear devices, to design military equipment that could withstand the effects of a nuclear detonation, and to determine the military requirements for future nuclear device designs. In addition to participation in these projects, DOD personnel at HARDTACK II provided air and ground support, including radiological safety monitoring, and administrative staff support (21: 1,29,2).

4.17.3 Dose Summary for Operation HARDTACK II.

HARDTACK II participants, with the exception of AFSWC personnel on cloud-sampling missions, were limited to a gamma plus neutron dose of 3.0 rem per calendar quarter or a total of 5.0 rem per year. The AFSWC personnel involved in cloud sampling were permitted to receive up to 10.0 rem during the series. Individuals who participated in cloud sampling at HARDTACK II who were also at HARDTACK I were authorized to receive 15 rem for the total operation (21: 5,74). The table below summarizes doses for both the weapons-related events and the safety experiments:

Summary of External Doses for Operation HARDTACK II as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	45	64	200	15	5	1
Navy	31	0	1	1	0	0
Air Force	204	19	27	5	2	0
Marine Corps	2	0	0	0	0	0
Civilian DOD Participants	952	35	20	2	0	0

4.18 SAFETY EXPERIMENTS.

The nuclear weapons testing program included 33 safety experiments, conducted at the NTS from 1955 to 1958 (22: 8,9,11,12; 17: 9):

- Four experiments called PROJECT 56 and conducted in November 1955 and January 1956, after Operation TEAPOT
- Six experiments called PROJECT 57 and conducted in April, July, August, and September 1957 before and during Operation PLUMBBOB
- Four experiments identified as PROJECT 58 and conducted in December 1957 and February and March 1958, after Operation PLUMBBOB
- Nineteen experiments conducted from July to October 1958 during Operations HARDTACK I and II.

Eleven of the tests were surface detonations, while nine occurred in shafts, six in tunnels, and one on a barge. Of the remaining safety experiments, five were tower detonations and one was a balloon test. Ten of the experiments had no measurable yield while one, COULOMB C, had 0.5 kiloton, which was the highest yield of any safety experiment.

4.18.1 Objectives of the Safety Experiments.

Except for one PROJECT 57 test, the safety experiments were conducted for the same purpose: to determine the weapons' susceptibility to nuclear detonation during accidents in storage and transportation. High-explosive portions of these devices were fired to simulate accidental detonation and to determine the potential for such firings to result in a significant nuclear yield. The test results were used to develop devices that could withstand shock, blast, fire, and accidents without initiating a nuclear chain reaction and producing a nuclear detonation. The initial PROJECT 57 test was conducted to spread alpha-emitting material (plutonium) in a defined area to study the biological effects of alpha radiation and to test monitoring and decontamination procedures (22: 23,8).

4.18.2 Test Operations at the Safety Experiments.

DOD personnel participation during these experiments is difficult to determine. Although most of the employees of LANL and LLNL were civilians, some DOD personnel also were assigned to these organizations. In addition, some of the project activities engaged DOD participation. Eight AFSWC personnel and two participants from the 50th Chemical Service Platoon performed field work for one of the programs during PROJECT 57, the alpha-dispersion experiment. Moreover, a DOD effects project was conducted at four of the safety experiments. Other DOD participation involved cloud-tracking and cloud-sampling missions (22: 12; 17: 184,185).

4.18.3 Dose Summary for the Safety Experiments.

Section 4.17 presents information on personnel doses at the 18 HARDTACK II safety experiments. The limited dosimetry information on the other safety experiments indicates four doses exceeding the 3.9 rem limit at Experiment 4 of PROJECT 56. The readings, which may have resulted from the participants' having handled hot instrumentation cable, were 28, 18.5, 13.7, and 4.3 rem (22: 21).

4.19 OPERATION DOMINIC I.

Operation DOMINIC, like Operation HARDTACK, consisted of two phases: DOMINIC I, the oceanic nuclear tests discussed in this section; and DOMINIC II, the continental tests considered in section 4.20. The DOMINIC shots, also named Operation SUNBEAM by DOD, were the last atmospheric nuclear weapons tests conducted by the United States (23: 1).

DOMINIC I consisted of the 36 nuclear tests identified in the accompanying table. Most of the shots were detonated in the air after having been dropped from B-52 bombers. Twenty-four of the airdrops took place from 25 April through 11 July over the ocean just south of Christmas Island, United Kingdom territory 1,200 nautical miles south of Honolulu. Five more airdrops were detonated in October over the open ocean in the vicinity of Johnston Island, U.S. territory 780 nautical miles west-southwest of Honolulu. The five rocket shots, designated FISHBOWL events, were launched from Johnston Island and detonated at high altitudes, up to 400 kilometers. The Navy conducted the other two shots: FRIGATE BIRD, launched by a Polaris missile from the submarine USS Ethan Allen and detonated east of Christmas Island; and SWORDFISH, a rocket-launched antisubmarine nuclear depth charge detonated 400 miles west of San Diego (23: 1,2). Figure 16 shows the SWORDFISH spray dome and the USS Agerholm (DD-286), from which the rocket was fired (I).

4.19.1 Background and Objectives of Operation DOMINIC I.

The U.S. did not conduct any nuclear tests from 30 October 1958, the date of the last HARDTACK II test, to 15 September 1961, when the U.S. resumed underground nuclear testing at the NTS. On 1 November 1958, the U.S. initiated its 1-year suspension of nuclear testing, which was later extended throughout 1959. On 29 December 1959, the U.S. announced an end to its moratorium, effective 31 December, but with a promise not to resume testing without advance public notice (23: 25).

On 3 January 1960, the Soviet Premier pledged that the Soviet Union would not conduct nuclear tests unless the Western nations resumed their testing. On 31 August 1961, however, the U.S.S.R. abruptly announced plans to resume atmospheric testing and then detonated a nuclear device at the Semipalatinsk test range in Central Asia the next day. This began an extensive Soviet series that continued into November and included more than 30 nuclear shots, among which were a 58-megaton detonation (the largest ever) and high-altitude tests. U.S. testing recommenced with a tunnel shot at the NTS, 15 September

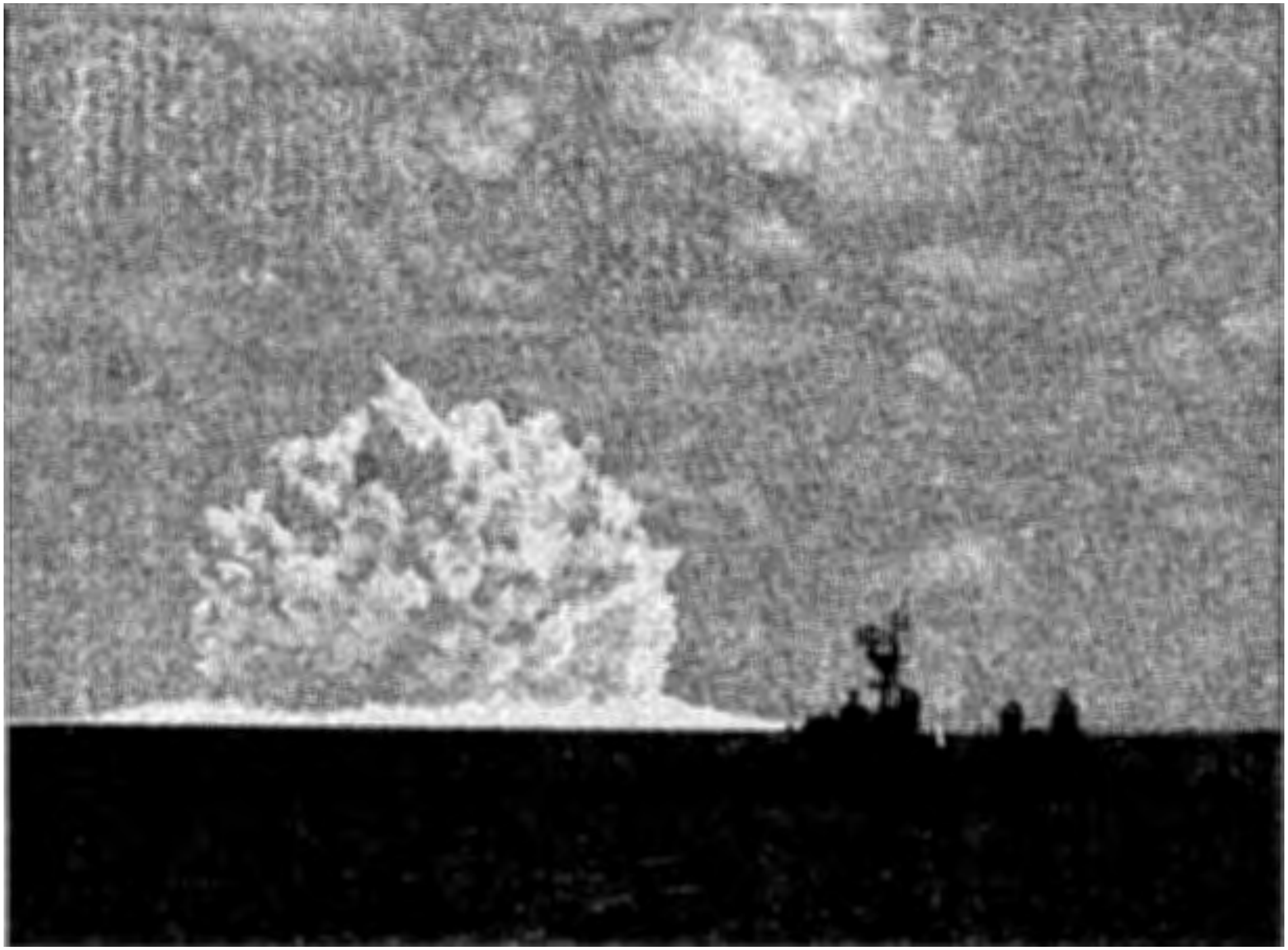

Figure 16. SWORDFISH spray dome with *USS Agerholm* (DD-826) in the foreground, 11 May 1962.

1961, followed by a series of underground tests. The President approved planning for atmospheric tests on 10 October 1961 but did not approve DOMINIC until 2 March 1962 (23: 25).

Operation DOMINIC I was conducted with four primary objectives: to develop nuclear weapons (the 29 airdrops); to study the effects of nuclear detonations (the five high-altitude bursts); to test the Polaris weapon system (the FRIGATE BIRD event); and to test the Navy nuclear antisubmarine rocket (Shot SWORDFISH) (23: 1).

Operation DOMINIC I Test Events, 1962

Event	Date	Type	Yield*
ADOBE	25 April	Airdrop	Intermediate
AZTEC	27 April	Airdrop	Intermediate
ARKANSAS	2 May	Airdrop	Low megaton range
QUESTA	4 May	Airdrop	Intermediate
FRIGATE BIRD	6 May	Rocket	NA**
YUKON	8 May	Airdrop	Intermediate
MESILLA	9 May	Airdrop	Intermediate
MUSKEGON	11 May	Airdrop	Intermediate
SWORDFISH	11 May	Underwater	Low
ENCINO	12 May	Airdrop	Intermediate
SWANEE	14 May	Airdrop	Intermediate
CHETCO	19 May	Airdrop	Intermediate
TANANA	25 May	Airdrop	Low
NAMBE	27 May	Airdrop	Intermediate

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*Low yield is less than 20 kilotons, and intermediate yield is 20-1,000 kilotons.

**Not announced.

Operation DOMINIC I Test Events, 1962 (Continued)

Event	Date	Type	Yield
ALMA	8 June	Airdrop	Intermediate
TRUCKEE	9 June	Airdrop	Intermediate
YESO	10 June	Airdrop	Low megaton range
HARLEM	12 June	Airdrop	Intermediate
RINCONADA	15 June	Airdrop	Intermediate
DULCE	17 June	Airdrop	Intermediate
PETIT	19 June	Airdrop	Low
OTOWI	22 June	Airdrop	Intermediate
BIGHORN	27 June	Airdrop	Megaton range
BLUESTONE	30 June	Airdrop	Low megaton range
STARFISH PRIME	8 July	Rocket	1.4 megatons
SUNSET	10 July	Airdrop	Intermediate
PAMLICO	11 July	Airdrop	Low megaton range
ANDROSCOGGIN	2 October	Airdrop	Intermediate
BUMPING	6 October	Airdrop	Low
CHAMA	18 October	Airdrop	Low megaton range
CHECKMATE	19 October	Rocket	Low
BLUEGILL 3 PRIME	25 October	Rocket	Submegaton
CALAMITY	27 October	Airdrop	Intermediate
HOUSATONIC	30 October	Airdrop	Megaton range
KINGFISH	1 November	Rocket	Submegaton
TIGHTROPE	3 November	Rocket	Low

4.19.2 DOMINIC I Test Operations.

The estimated 22,600 participants in DOMINIC I were from all four military services, as well as from DOD agencies, AEC organizations, DOD and AEC contractors, and various Federal agencies. The DOD participation was extensive in all parts of the DOMINIC I experimental program: weapons development, weapons effects, and operational tests. Even the experimental program for the weapon development shots at Christmas Island and later at

Johnston Island, conducted by AEC laboratories, involved DOD personnel and units for device placement, cloud sampling, operation of airborne data recording stations, and general support. The weapons effects and operational tests were DOD programs, the former involving a number of experimental projects (23: 11).

4.19.3 Dose Summary for Operation DOMINIC I.

With exceptions for specified Navy and Air Force participants, the maximum permissible dose for Operation DOMINIC I personnel was 3.0 rem of gamma radiation for the series. Navy personnel who were to collect samples of weapon debris from the radioactive pool of water created by SWORDFISH were authorized a maximum limit of 7.0 rem. Air Force personnel associated with cloud sampling (crew, maintenance, sample removal, or decontamination) could receive up to 20 rem of gamma radiation (23: 3).

The table below summarizes available dosimetry information for DOMINIC I participants. Existing evidence indicates that some of the film badges had been defectively sealed or damaged by the environment and that they gave higher readings than the dose actually received. Nevertheless, all personnel have been assigned the readings recorded in Navy records (23: 3,4).

Summary of External Doses for Operation DOMINIC I as of 1 May 1986
Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	587	8	19	2	0	0
Navy	17,604	205	344	9	1	0
Air Force	2,557	83	98	11	19	21
Marine Corps	653	1	5	0	0	0
Civilian DOD Participants	190	2	1	0	0	0

4.20 OPERATION DOMINIC II.

Also known by the DOD code name of Operation SUNBEAM, DOMINIC II was the continental phase of the DOMINIC nuclear tests. The four shots of this series were conducted at the NTS from 7 July through 17 July 1962, during the period of DOMINIC I, the nuclear test series conducted at the Pacific Proving Ground from 25 April through 3 November 1962 (24: 1).

DOMINIC II consisted of the four low-yield shots identified below. LITTLE FELLER I, one of the surface shots, was part of Exercise IVY FLATS, the only military training exercise conducted at DOMINIC II (24: 1,5).

Event	Date	Type	Yield (kilotons)
LITTLE FELLER II	7 July	Surface	Low
JOHNIE BOY	11 July	Crater	0.5
SMALL BOY	14 July	Tower	Low
LITTLE FELLER I	17 July	Surface	Low

4.20.1 Background and Objectives of Operation DOMINIC II.

The United States resumed nuclear weapons testing on 15 September 1961 with a series of underground tests conducted at the NTS: Operation NOUGAT, 15 September 1961 to 30 June 1962. This was followed by another underground series: Operation STORAX, 6 July 1962 to 25 June 1963. Operation DOMINIC II was conducted during the period of Operation STORAX but was not a part of STORAX (24: 19,20).

Operation DOMINIC II, designed to provide information on weapons effects, originally comprised only Shot SMALL BOY. Subsequent plans were to include three Little Feller shots, one 3 feet above ground, another 40 feet above ground, and the third also at a height of 40 feet, having been launched tactically as part of a military exercise. The third shot was, however, canceled, and the second, which became LITTLE FELLER I, was changed to a 3-foot shot to be launched in connection with a tactical maneuver (24: 1,114,73).

Plans for JOHNIE BOY, the last shot added to the series, were not made until May 1962. Detonated 2 months later, JOHNIE BOY was designed to explore the cratering effects of a subkiloton nuclear device fired in a shallow emplacement (24: 94).

4.20.2 DOMINIC II Test Operations.

An estimated 2,900 DOD military and civilian personnel participated at Operation DOMINIC II in Exercise IVY FLATS (Shot LITTLE FELLER I), scientific and diagnostic tests, and air support or administrative support activities. Approximately 1,000 of these participants were Sixth Army military personnel who took part in Exercise IVY FLATS, which consisted of an observer program and a troop maneuver. The observers, who wore protective goggles, witnessed the detonation from bleachers about 3.5 kilometers southwest of ground zero. Five participants from the IVY FLATS maneuver task force launched the weapon from a rocket launcher mounted on an armored personnel carrier. After the initial radiological surveys were completed, the IVY FLATS troops entered their vehicles and moved into the shot area, where they spent about 50 minutes conducting maneuvers (24: 1,3).

4.20.3 Dose Summary for Operation DOMINIC II.

Most DOMINIC II participants were subject to a quarterly dose limit of 3.0 rem (gamma plus neutron) and an annual limit of 5 rem (gamma plus neutron). Cloud-sampling pilots were authorized to receive up to 3.9 rem per 13-week period because their mission sometimes required them to penetrate the clouds (24: 3,7).

The following table summarizes the dosimetry data available for DOMINIC II, as well as for the first two events of the PLOWSHARE Program, GNOME and

SEDAN, which are discussed in section 4.21. GNOME was conducted on 10 December 1961 and SEDAN on 6 July 1962. A number of DOD participants in these two events also took part in DOMINIC II. In many cases, their recorded doses were cumulative, covering their participation in both DOMINIC II and the PLOWSHARE events. For this reason, the combined totals are provided for DOMINIC II, GNOME, and SEDAN, as is shown below:

Summary of External Doses for Operation DOMINIC II
and for GNOME and SEDAN of the PLOWSHARE Program as of 1 May 1986

Gamma Dose (rem)

	0-0.5	0.5-1	1-3	3-5	5-10	10+
Army	1,184	163	101	2	0	0
Navy	61	19	32	0	1	0
Air Force	235	28	14	1	0	0
Marine Corps	37	8	16	1	0	0
Civilian DOD Participants	638	21	10	0	0	0

4.21 PLOWSHARE PROGRAM.

Conducted from 1961 to 1973, the PLOWSHARE Program consisted of 27 nuclear detonations, four of which occurred before the signing of the 1963 limited test ban treaty. The detonations, all of which had yields of no more than 200 kilotons, were staged at the NTS and other sites in Colorado and New Mexico. The tests were all subsurface, being either shaft or cratering shots (25: 1).

As indicated by the following table, this section discusses only Projects GNOME and SEDAN, the first two PLOWSHARE events. These two shots were selected for consideration because they were conducted during the period of U.S. atmospheric testing and they had documented, although limited, DOD participation. In addition, the extant sources were sufficient in number and detail to enable a summation of the events (25: 1).

Event	Date	Type	Yield (kilotons)
GNOME	10 December 1961	Shaft	3
SEDAN	6 July 1962	Crater	104

4.21.1 Background and Objectives of the PLOWSHARE Program.

From the earliest days of nuclear research and nuclear weapons testing, scientists were aware of the potential for peaceful applications of nuclear energy, including nuclear detonations. This recognition became U.S. policy in the Atomic Energy Act of 1946, which stated that "atomic energy is capable of application for peaceful as well as military purposes." The opportunity for American scientists to apply nuclear detonations to peaceful ends was delayed, however, by several factors, including the greater priority of developing efficient weapons applications, concern over radioactive contamination, and international suspicion of the intent of the research. Nevertheless, the AEC ultimately succeeded in initiating the PLOWSHARE Program, which had been planned in the late 1950s (25: 19,17,18).

The PLOWSHARE detonations were designed to determine nonmilitary applications of nuclear explosives. The primary potential use envisioned was in large-scale geographic engineering, in such projects as canal, harbor, and dam construction, the stimulation of oil and gas wells, and mining. GNOME was planned in part to provide information on the characteristics of an underground nuclear detonation in a salt medium, while SEDAN was to extend knowledge on cratering effects from detonations with yields of 100 to 200 kilotons. Considering the peaceful objectives of PLOWSHARE, the AEC took the name of the program from the Bible: "And they shall beat their swords into plowshares" (Isaiah 2:4) (25: 1-3).

The ultimate goal of PLOWSHARE, the peaceful applications of nuclear explosives, was never realized. The limited test ban treaty, signed on 5 August 1963 in Moscow, ended nuclear testing in the atmosphere, on land, and underwater, although not underground. Hence, a number of the PLOWSHARE experiments had to be canceled. Other contributing factors were changes in national priorities, Government and industry disinterest in the program, public concern over the health and safety aspects of using nuclear detonations for civil applications, and shortages of funding (25: 26).

4.21.2 PLOWSHARE Test Operations.

The Lawrence Livermore National Laboratory, which provided technical direction for the PLOWSHARE Program, conducted an extensive series of scientific projects at GNOME and SEDAN. Given the objectives of PLOWSHARE, the DOD did not stage military exercises during the program and had limited involvement in the shots. The primary role of the military was to provide logistical support. DOD personnel did, however, participate at GNOME and SEDAN in the VELA UNIFORM program, conducted by the DOD to develop U.S. capabilities in detecting and identifying underground nuclear detonations. In addition, the Air Force Special Weapons Center performed cloud-sampling, cloud-tracking, and support missions at the shots (25: 1-3).

4.21.3 Dose Summary for the PLOWSHARE Program.

PLOWSHARE participants were limited to 3.0 rem of gamma and neutron radiation per calendar year and not more than 5.0 rem annually. The dosimetry information available for GNOME and SEDAN participants is included in the dose summary table given in section 4.20.

SECTION 4

REFERENCE LIST

1. "Project TRINITY, 1945-1946." Wash., DC.: DNA. DNA-6028F. Jan 83. 74 p. (A04)AD/A128 035.*/**

2. *July 16th Nuclear Explosion--Safety and Monitoring of Personnel*. Paul Abersold. Los Alamos, NM.: LASL. LA-616. Jan 47. 170 p.***

3. *Operation CROSSROADS, 1946*. WASH., DC.: DNA. DNA-6032F. May 84. 568 p. (A24)AD/A146 562.*/**

4. *No Place to Hide, 1946/1984*. David Bradley. Hanover, NH.: University Press of New England. c1983. 217 p.

5. *Operation SANDSTONE, 1948*. Wash., DC.: DNA. DNA-6033F. Dec 83. 222 p. (A10)AD/A139 151.*/**

6. *Operation Ranger--Shots ABLE, BAKER, EASY, BAKER-2, FOX--25 January - 6 February 1951*. Wash., DC.: DNA. DNA-6022F. Feb 82. 182 p. (A09)AD/A118 684.*/**

7. *Operation GREENHOUSE, 1951*. Wash., DC.: DNA. DNA-6034. Jun 83. 334 p. (A15)AD/A134 735.*/**

8. *Operation BUSTER-JANGLE, 1951*. Wash., DC.: DNA. DNA-6023F. Jun 82. 190 p. (A09)AD/A123 441.*/**

9. *Operation TUMBLER-SNAPPER, 1952*. Wash., DC.: DNA. DNA-6019F. Jun 82. 218 p. (A10)AD/A122 242.*/**

10. *Operation IVY, 1952*. Wash., DC.: DNA. DNA-6036F. Dec 82. 364 p. (A16)AD/A128 082.*/**

11. *Operation UPSHOT-KNOTHOLE, 1953*. Wash., DC.: DNA. DNA-6014F. Jan 82. 266 p. (A12)AD/A121 624.*/**

12. *Shots ENCORE - CLIMAX--The Final Four Tests of the UPSHOT-KNOTHOLE Series, 8 May - 4 June 1953*. Wash., DC.: DNA. DNA-6018F. Jan 82. 232 p. (A11)AD/A121 634.*/**

13. *CASTLE SERIES, 1954*. Wash., DC.: DNA. DNA-6035F. Apr 82. 530 p. (A23)AD/A117 574.*/**

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See Availability Information page in Appendix E.

*Available from NTIS; price code and order number appear before the asterisk.

**Available at CIC.

***Declassification process pending. Requests subject to Privacy Act restrictions.

SECTION 4

REFERENCE LIST (Continued)

15. *Operation TEAPOT, 1955.* Wash., DC.: DNA. DNA-6009F. Nov 81. 274 p. (A12)AD/A113 537.*/**

16. *Operation WIGWAM (Series Volume).* Wash., DC.: DNA. DNA-6000F. Sep 81. 262 p. (A12)AD/A105 685.*/**

17. *Operation REDWING, 1956.* Wash., DC.: DNA. DNA-6037F. Aug 82. 442 p. (A19)AD/A134 795.*/**

18. *PLUMBBOB Series, 1957.* Wash., DC.: DNA. DNA-6005F. Sep 81. 312 p. (A14)AD/A107 317.*/**

19. *Operation HARDTACK I, 1958.* Wash., DC.: DNA. DNA-6038F. Dec 82. 474 p. (A20)AD/A136 819.*/**

20. *Operation ARGUS, 1958.* Wash., DC.: DNA. DNA-6039F. Apr 82. 138 p. (A07)AD/A122 341.*/**

21. *Operation HARDTACK II, 1958.* Wash., DC.: DNA. DNA-6026F. Dec 82. 242 p. (A11)AD/A130 929.*/**

22. "Safety Experiments, November 1955 - March 1958." Wash., DC.: DNA. DNA-6030F. Aug 82. 78 p. (A05)AD/A123 423.*/**

23. *Operation DOMINIC I, 1962.* Wash., DC.: DNA. DNA-6040. Feb 83. 436 p. (A19)AD/A136 820.*/**

24. *Operation DOMINIC II--Shots LITTLE FELLER II, JOHNIE BOY, SMALL BOY, LITTLE FELLER I--7 July - 17 July 1962.* Wash., DC.: DNA. DNA-6027F. Jan 83. 218 p. (A10)AD/A128 367.*/**

25. *Projects GNOME and SEDAN, the PLOWSHARE Program.* Wash., DC.: DNA. DNA-6029F. Mar 83. 183 p. (A07)AD/A130 165.*/**

See Availability Information page in Appendix E.
*Available from NTIS; price code and order number appear before the asterisk.
**Available at CIC.

SECTION 4

PHOTOGRAPHIC CREDITS

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B. Army, Signal Corps Photograph, SC 400726. B-38-5, Stewart. 2 May 1952.

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D. Army, Signal Corps Photograph, SC 425136. 25 May 1953.

E. Army, Signal Corps Photograph. 1953. [Additional identification unknown.]

F. Air Force, Lookout Mountain Laboratory Photograph, 22-AQB-1-13, BRAVO. 1954.

G. Army, Signal Corps Photograph, SC 504548. 30-006-AT160/APS-55-2546, Fangmann. 23 March 1955.

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I. Joint Task Group 8, Fig. 80 DOMINIC, "Spray Dome." 1962.

SECTION 5

RADIATION SAFETY AT THE ATMOSPHERIC NUCLEAR TESTS

The possible hazards associated with exposure to ionizing radiation were a major concern to the planners of the nuclear tests. Consequently, many of the Nation's leading experts on the subject were consulted and often served as staff members for each operation. A Health Group consisting of 35 personnel was established for Shot TRINITY, detonated on 16 July 1945 as the first test of a nuclear weapon. The group was headed by Dr. Louis Hempelmann, Medical Director of the Los Alamos National Laboratory; he reported to the test director, Dr. Kenneth T. Bainbridge. Colonel Stafford Warren, medical advisor to the Commanding General of the Manhattan Project, served as a special consultant. The primary function of the group was to provide for the safety of project personnel, as well as offsite citizens. This emphasis on radiation protection was evident throughout the nuclear test program.

Some nuclear test participants were exposed to initial radiation (neutron and gamma rays) emitted from the fireball and the cloud column during the first minute after the detonation. Others were exposed to residual radiation, which is emitted primarily by radioactive fission products and other bomb debris in fallout and by neutron-induced radioactivity in the soil and structures in proximity to the detonation. The following sections discuss general protective procedures against initial and residual radiation, with the emphasis on residual radiation. The references are listed in chronological order according to series and given at the end of the chapter.

5.1 PROTECTION AGAINST INITIAL RADIATION.

Protection from initial radiation was provided by ensuring that test participants were positioned at a safe distance from the detonation. The safe distance was usually calculated from empirically or theoretically derived equations that considered such factors as the type or design of the nuclear device, the expected yield of the device, environmental conditions including humidity, and any shielding between the detonation and the participant. For several of the CONUS tests, for example, military maneuver and observer troops were situated in trenches that were 3.2 to 4.6 kilometers from ground zero and that provided considerable shielding. Unshielded participants were customarily positioned much further away from ground zero.

5.2 PROTECTION AGAINST RESIDUAL RADIATION.

Procedures for protection against residual radiation were more complex because operations in a contaminated environment involved potential exposure to radiation sources both external to and inside the body, the latter resulting primarily from inhalation or ingestion of radioactive material. The next sections address these protective measures.

5.2.1 Identification and Control of Radiation Areas.

The fundamental approach for protection against residual radiation was to control access to contaminated areas. Obviously, the first step was the identification of the radiation areas and quantification of the radiation therein. In all cases, **authorized** entry into a radiation area was made through a control point and preceded by some form of survey by trained radiation monitors using state-of-the-art radiation detection and measurement equipment. In the case of a military maneuver, radiation monitors preceded the advancing troops to steer them away from radiation areas contaminated above pre-established limits. Re-entry into the shot area by scientific project personnel or military troops visiting a display area normally was delayed until a "Recovery Hour" was declared after completion of an initial radiation survey of the area. The initial survey team used radiation detectors to locate and mark various radiation intensities approaching the detonation site. In some cases, early entry was authorized for certain scientific project personnel; however, these personnel were accompanied by their own radiation monitors.

The radiation levels measured by these monitors were used to determine the amount of time the participants could remain in the area. "Stay times" were calculated and observed to ensure that external gamma radiation exposure limits were not exceeded. Only gamma radiation was considered for this purpose since normal clothing provided adequate protection against external alpha and beta radiation exposure.

The possible spread of contamination to clean areas was controlled by requiring personnel who entered a contaminated area to exit through a check point where they could be monitored and decontaminated as necessary. Most scientific project or other personnel whose activities required entry into highly radioactive areas were issued anti-contamination clothing (including coveralls, booties, and gloves) that could be easily removed, if needed, at the check station decontamination point. It should be emphasized that such clothing did not provide any more protection against external radiation (alpha, beta, or gamma) than did ordinary clothing or military fatigues. This disposable clothing was provided simply as a convenience for contamination control and laundry purposes. Ordinary clothing and fatigues that could not be decontaminated also had to be replaced at the check station decontamination point.

5.2.2 Use of Radiation Detection and Measurement Instruments.

Monitors used several types of radiation survey instruments. The majority were gas-filled detectors, specifically ionization chamber, Geiger-Mueller counter, and gas-flow proportional counters. These detectors relate the intensity of the incident radiation to the effects of ionization produced by the radiation in a gas-filled "sensitive volume." Some of the other instruments took advantage of the fact that certain materials emit light when struck by radiation. These instruments, called scintillation detectors, simply relate the amount of light produced in the detection medium to the intensity of the incident radiation. Both gas-filled and scintillation detectors were used, depending upon the basic design of the instrument, to detect and measure alpha, beta, and/or gamma radiation.

The survey instruments mentioned above portray the radiation intensity in terms of rate (e.g., milliroentgens or roentgens per hour or counts per minute). In some cases, test participants were issued pocket dosimeters that provided information on cumulative exposure. These dosimeters, about the size and shape of a writing pen, consisted of a small ionization chamber coupled to a miniature electroscope. One type of pocket dosimeter (self-reading) included an optical system that allowed the wearer to determine his cumulative exposure while in the field. Other types required a separate charger-reader.

The primary device used to determine the wearer's cumulative radiation exposure was the film badge. A film badge consisted of one or more small pieces of photographic-type film wrapped in a paper packet and enclosed in a plastic envelope or other special metal or plastic holder that could be clipped or otherwise attached to the wearer's outer clothing. Film badges incorporated one or more special metal filters to improve performance. When processed, a film exhibited a darkening (net optical density) that is proportional to the cumulative radiation exposure. Optical density is measured with a densitometer and compared with a calibrated standard to determine total exposure. Film badges worn during the period of nuclear testing were primarily used to measure gamma radiation exposures. Some attempts (most unsuccessful) were made to measure beta radiation exposures, and special neutron film badges were employed during the later stages of the test program.

The Nuclear Test Personnel Review (NTPR) program has located a considerable number of film badge dosimetry records, which have been entered into the master repository of dose records maintained by Reynolds Electrical & Engineering Company. As indicated by table 4, presented in section 1.5 of this report, the vast majority of doses were well below established radiation protection standards. The records attest to the effectiveness of the radiation protection efforts made during the atmospheric nuclear testing.

Figure 17 shows a radiation monitor wearing protective clothing and using radiological safety equipment.* Table 9 provides a list of radiation detection and measurement instruments used for survey and personnel monitoring purposes. The list is not inclusive but identifies the instruments most commonly used. It is apparent that some instruments employed during an operation were replaced by improved equipment during subsequent operations. Other instruments, such as the MX-5, the T1B(AN/PDR-39), and the AN/PDR-27, were used (modified as necessary) for several years.

5.2.3 Protection Against Internal Doses.

As mentioned earlier, procedures for protection against residual radiation had to consider internal doses resulting from inhalation and ingestion of radioactive material. Administrative controls that prohibited eating in

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*Army, Signal Corps Photograph, SC 435932. 17 March 1953.

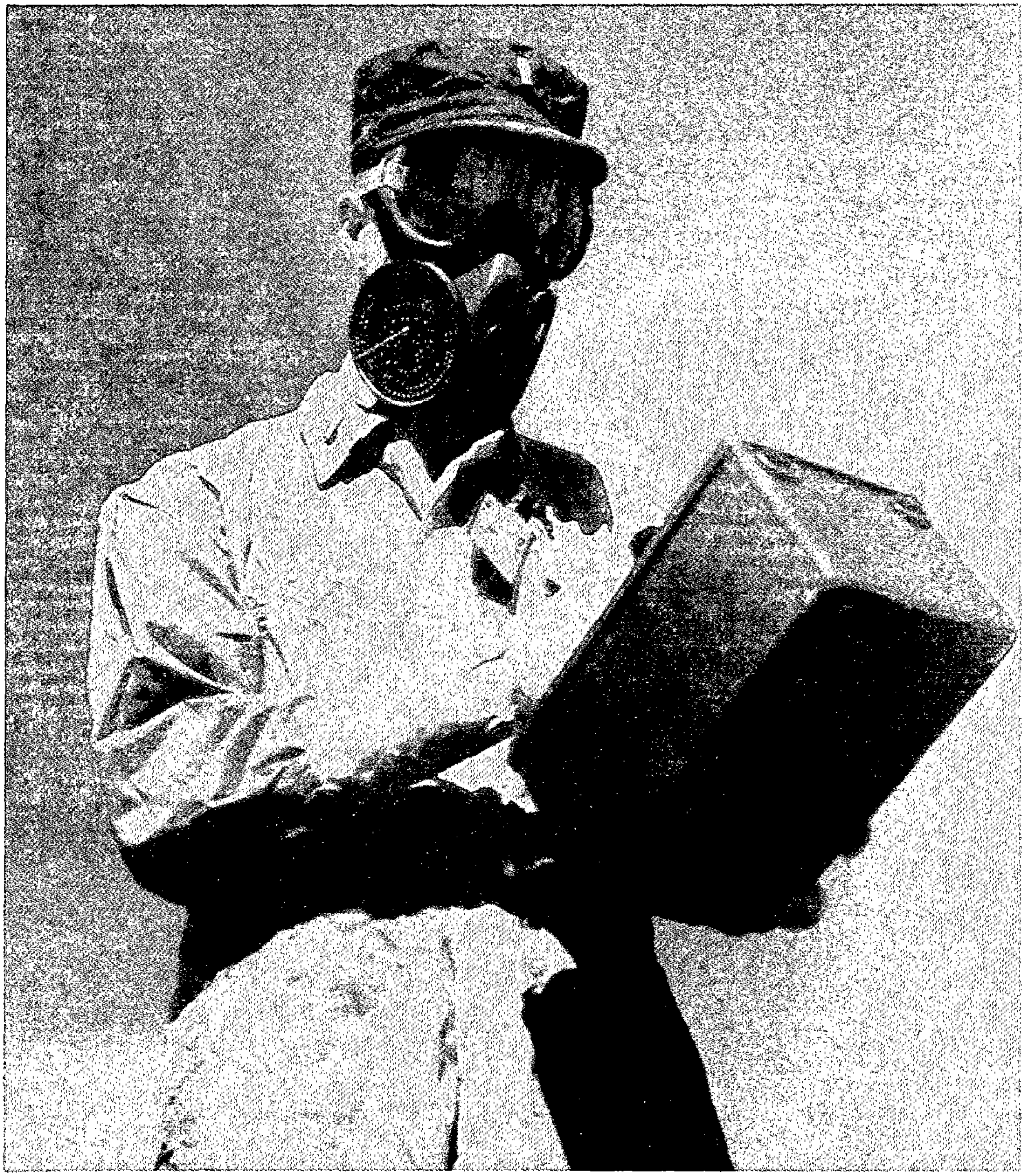

Figure 17. Radiation monitor wearing protective clothing and using radiological safety equipment.

Table 9. Radiation survey instruments used during nuclear tests.

Instrument Identification	Type	Radiation Detected/ Measured	Range (Scales)	TRINITY	CROSSROADS	SANDSTONE	RANGER	GREENHOUSE	BUSTER-JANGLE	TUMBLER-SNAPPER	IVY	UPSHOT-KNOTHOLE	CASTLE	TEAPOT	WIGWAM	REDWING	PLUMBBOB	HARDTACK I	HARDTACK II	DOMINIC I	DOMINIC II	PLOWSHARE
Unknown	Proportional Counter	A		●																		
Victoreen Model 247, Numerous Models	Ion Chamber	G	0-10R/HR (3)	●	●	●	●	●														
Hallicrafter Model 5	Geiger-Mueller	B, G	0-0.02 R/8HR (2)	●																		
Watts Meter	Ion Chamber	G		●	●	●	●															
Victoreen Model 263, AN/PDR-5	GM	B, G	0-20 MR/HR (3)		●	●	●	●														
Cutie-Pie, Various Makes and Models	Ion Chamber	B, G	0-100 R/HR (Varies)		●	●	●	●	●	●	●	●	●	●	●	●						
Victoreen-356 "Zeuto"	Ion Chamber	A, B, G	0-40 MR/HR (2)		●	●																
Instrument Development Lab Model 2610	GM	B, G	0-20 MR/HR (3)			●	●	●	●	●	●	●	●	●	●							
National Technical Lab NTL/Beckman Model MX-5	GM	B, G	0.2-20 MR/HR (3)			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
National Technical Lab Model MX-2	Ion Chamber	B, G	0-2000 MR/HR (5)			●																
National Technical Lab Model MX-6	Ion Chamber	B, G	0-5000 MR/HR (4)			●	●															
AN/PDR-8	GM	B, G	0-500 MR/HR (4)			●	●	●														
Pee Wee, Various Makes and Models	Prop. Counter	A	0-20K CPM (2) 0-2000K CPM (2)			●	●	●	●	●	●	●	●	●	●	●	●					
TIB, AN/PDR-39, SU-10 (Navy), Various Models	Ion Chamber	G	0-50K MR/HR (5) 0-500K (Some Models)				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Juno	Ion Chamber	A, B, G	0-1M DPM Alpha 0-50K MR/HR (3) Gamma				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
El Tronics SGM-18A	GM	B, G						●														
AN/PDR-27 Series, Numerous Models	GM	G	0-500 R/HR (4)					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Victoreen 389 THYAC	GM	B, G	0-20 MR/HR (3)									●	●	●	●	●	●	●	●			
AN/PDR-10 A, Poppy	Prop. Counter	A	0-10,000 CPM (2)									●										
AN/PDR-18	Scintillation	G	0-500 R/HR (4)										●	●	●	●	●	●				
Eberline PAC-1	Prop. Counter	A	0-100K CPM (3)														●					
Eberline PAC-1A	Prop. Counter	A	0-1M CPM (3)														●					
AN/PDR-43	GM	B, G	0-5R/HR (3)														●					
Eberline PAC 2G, 3G	Prop. Counter	A	0-100K CPM (3)															●	●	●	●	●
CDV-700	GM	B, G	0-50 MR/HR (3)															●				
Eberline E-500 B	GM	B, G G	0-200 MR/HR (4) 0-2000 MR/HR (4)																	●	●	●
IM-108	Ion Chamber	G	0-500 R/HR																	●		
Eberline-112 B	GM Scintillation	B, G A	0-20 MR/HR																	●	●	
Victoreen/Jordan ABG "RAD-Gun"	Ion Chamber	B, G	0-10K R/HR (Log)																		●	●
Victoreen/Jordan Radector	Ion Chamber	G	0-500R/HR (2)																		●	●

contaminated areas were established in consideration of the latter. Respiratory protection (respirators) normally was provided for scientific project personnel involved in operations where inhalation of radioactive material was considered a potential problem. Military maneuver troops carried standard gas masks for use in dusty, possibly radioactive environments.

The degree of internal exposure resulting from inhalation or ingestion of radioactive material by DOD test participants was not routinely monitored. Other than a considerable number of urine and blood samples analyzed during Operation CROSSROADS, bioassays were rare among military personnel. To fill this gap in the data base, a methodology has been developed to calculate internal doses from reconstructed exposure scenarios and radiological environments, as noted in chapter 7. Using a comprehensive screening methodology, the dose commitment due to internal emitters has been determined to be less than 0.15 rem to the bone for more than 170,000 test participants. The research and subsequent screening of additional personnel is continuing, and indications are that many more participants will be found to have a bone dose commitment of less than 0.15 rem. This level is 1 percent of the dose limit recommended by the National Council on Radiation Protection and Measurements.

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This chapter has discussed general radiation safety only at the nuclear tests. The next chapter considers the U.S. occupation of Hiroshima and Nagasaki, focusing on radiation surveys, patterns of residual radiation, and radiation doses.

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SECTION 6

THE ATOMIC BOMBING AND U.S. OCCUPATION OF HIROSHIMA AND NAGASAKI

Having tested Project TRINITY in New Mexico on 16 July 1945, the United States had two atomic bombs ready for use in early August 1945. They were both dropped on Japan, the first over Hiroshima on 6 August 1945 and the second over Nagasaki on 9 August. The Hiroshima weapon was smaller, with a yield of about 15 kilotons compared to the 21 kilotons for the Nagasaki detonation. As planned, they both were air bursts, the first at about 1,900 and the second at 1,650 feet above the city. The burst height was the key factor in preventing any significant residual contamination.

Vivid descriptions of the detonations appear in a number of sources, including John Hersey's Hiroshima (1946) and Takashi Nagai's We of Nagasaki (1951):

- A tremendous flash of light cut across the sky. . . . It seemed a sheet of sun (Hersey, p. 8).
- The red was bright enough to stun a person, but the blue! -- it was so bright that not even the worst liar could have found the words to express it (Nagai, p. 31).
- It was getting dark and cold very fast. I thought an airplane must have crashed into the sun (Nagai, p. 23).

The objective of the bombings was to bring World War II to a quick end, thereby avoiding the death and destruction that would inevitably result from the planned invasion of the Japanese home islands. During the U.S. invasion of Okinawa, 1 April 1945 through 21 June 1945, the U.S. casualties included about 12,000 killed, and the Japanese losses approached 100,000 killed. On 26 July 1945, President Harry Truman urged the Japanese to surrender unconditionally or face "prompt and utter destruction." The Japanese ignored the warnings, having heard similar predictions before fire raids. Subsequently, they experienced the loss of more than 75,000 people in Hiroshima and more than 35,000 in Nagasaki. On 2 September 1945, Japan officially surrendered to Allied forces. The early radiation surveys and the American occupation of Hiroshima and Nagasaki followed shortly thereafter.

6.1 EARLY RADIATION SURVEYS.

In the months immediately following the detonations, U.S. scientists conducted a number of onsite surveys to be sure that any residual radiation in Hiroshima and Nagasaki would not present a health hazard to occupation troops or to the Japanese remaining in the cities. General Marshall, U.S. Army Chief of Staff in Washington, addressed the first concern in a message sent to General MacArthur, the Theater Commander. General Marshall emphasized the importance of early radiation surveys so that the occupation troops "shall not be subjected to any possible toxic effects, although we have no reason to believe that any such effects actually exist." Three series of early radiation surveys followed:

- Scientists from the Manhattan Engineer District, the organization that had developed the bombs, made rapid radiation surveys of Hiroshima on 8-9 September 1945 (1 month before occupation troops arrived in that area) and of Nagasaki on 13-14 September (10 days before the occupation troops arrived).
    - They reported negligible levels of radioactivity in the areas surveyed.
- The Manhattan Project Atomic Bomb Investigating Group made more extensive surveys in Nagasaki from 20 September to 6 October and in Hiroshima from 3 to 7 October 1945.
    - Their measurements, detailed in extensive reports, showed the levels of residual radioactivity to be extremely low.
- The Naval Technical Mission to Japan surveyed Nagasaki during 15 to 27 October and Hiroshima on 1 to 2 November 1945.
    - Their well-documented findings of negligible levels of radioactivity corroborated the earlier measurements.

In addition to these surveys, the U.S. investigation teams used data from numerous separate radiation monitoring surveys, soil and debris sampling programs, and other analyses conducted by Japanese scientists in the days and weeks immediately following the bombings.

The initial and rapid measurements taken by the Manhattan Engineer District served the critically important purpose of allowing the American occupation of Hiroshima and Nagasaki to proceed as scheduled. The more extensive surveys by the Manhattan Project Atomic Bomb Investigating Group and the Naval Mission to Japan resulted in reports since regarded as basic source documents and included in the references appended to the end of this chapter.

6.2 RESIDUAL RADIATION IN HIROSHIMA AND NAGASAKI.

After the bombings, one area of low-level residual radioactivity remained around ground zero in each city and in areas downwind of each city. The former was induced radioactivity, and the latter was caused by fallout.

6.2.1 Induced Radioactivity at the Hypocenters.

Roughly circular patterns of residual radiation were created at the times of detonation, when the high-intensity burst of neutrons from the bomb encountered elements in the soil and building materials, such as concrete, metal, and tile, in the area beneath the detonation and caused them to become radioactive. (Examples of elements in which radioactivity can be induced are aluminum, sodium, manganese, cobalt, and cesium.) The induced radioactivity was of relatively low intensity because the detonation heights minimized the number of neutrons reaching the ground and because many of the induced activity radionuclides had short half-lives (the time required for the radiation intensity to be reduced from any given value to one-half that value). For example, aluminum-28 has a half-life of about 2.3 minutes, and manganese-56 has a half-life of about 2.6 hours.

When the first occupation troops entered Hiroshima 60 days after the detonation, the intensity of induced radioactivity around the hypocenter was 0.03 milliroentgen per hour,* as shown in figure 18. The highest intensity within this area was about 0.1 milliroentgen per hour. About the same levels of induced radioactivity remained in Nagasaki when the main body of occupation troops arrived 45 days after the bombing. Figure 19 shows an isointensity

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*A milliroentgen equals one-thousandth of a roentgen.

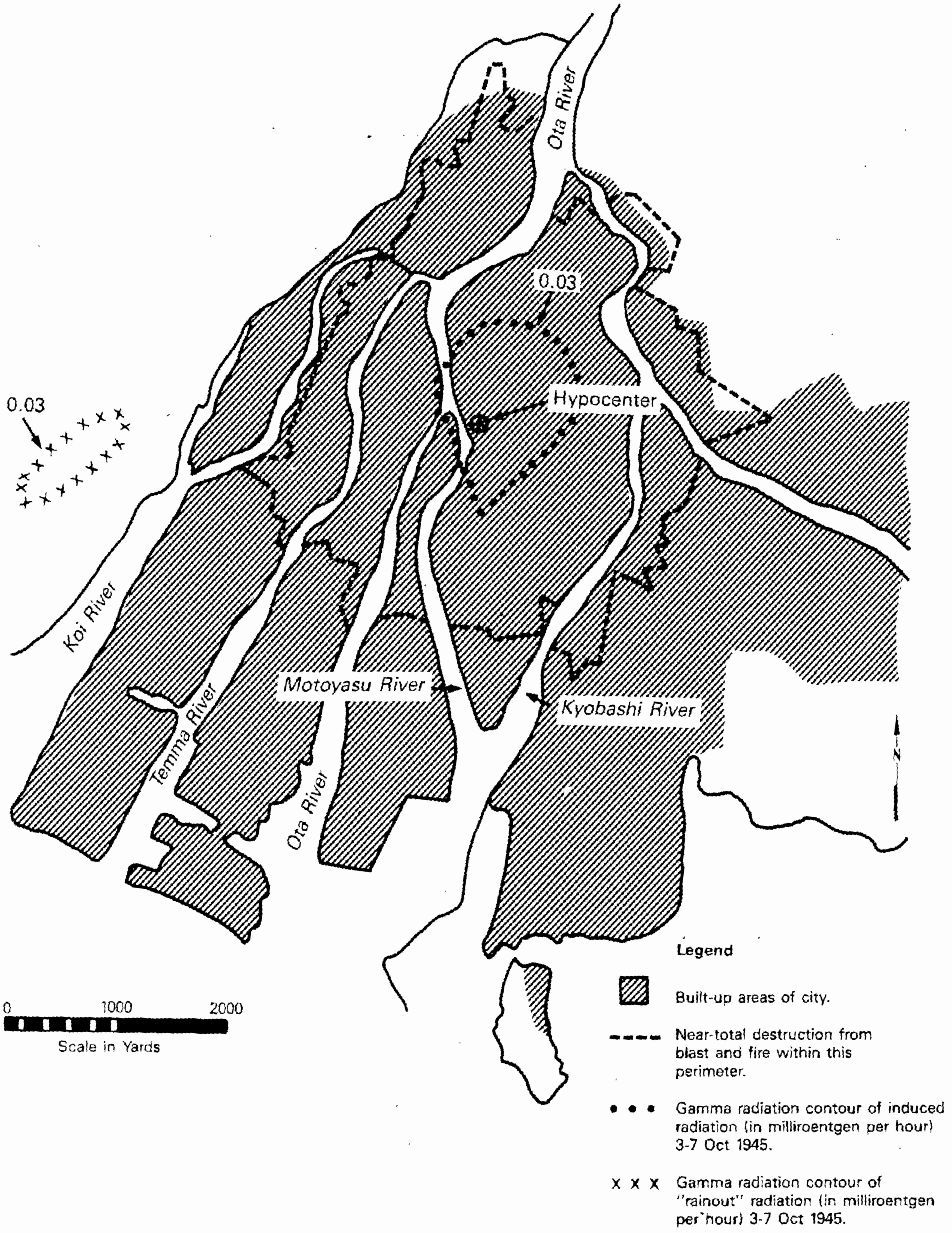
Ota River
0.03
0.03
Hypocenter
Koi River
Temma River
Motoyasu River
Kyobashi River
Ota River
N
0
1000
2000
Scale in Yards
Legend
▨ Built-up areas of city.
- - - - Near-total destruction from blast and fire within this perimeter.
• • • Gamma radiation contour of induced radiation (in milliroentgen per hour) 3-7 Oct 1945.
X X X Gamma radiation contour of "rainout" radiation (in milliroentgen per hour) 3-7 Oct 1945.

Figure 18. Hiroshima, Japan, 3-7 October 1945.

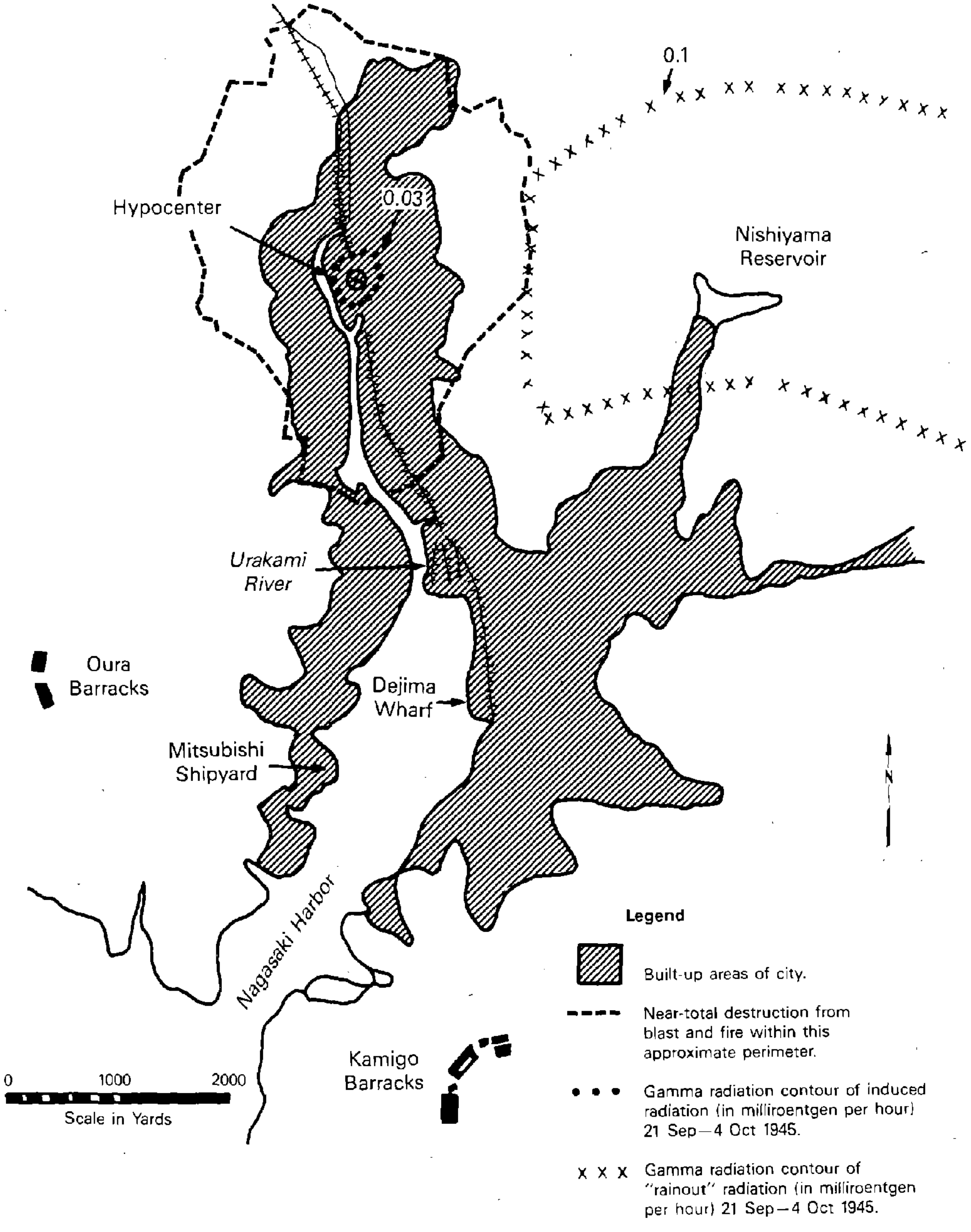
0.1
Hypocenter
0.03
Nishiyama
Reservoir
Urakami
River
Oura
Barracks
Dejima
Wharf
Mitsubishi
Shipyard
Nagasaki Harbor
N
Legend
Built-up areas of city.
Near-total destruction from blast and fire within this approximate perimeter.
Gamma radiation contour of induced radiation (in milliroentgen per hour) 21 Sep—4 Oct 1945.
Gamma radiation contour of "rainout" radiation (in milliroentgen per hour) 21 Sep—4 Oct 1945.
Kamigo
Barracks
0
1000
2000
Scale in Yards

Figure 19. Nagasaki, Japan, 21 September—4 October 1945.

contour of 0.03 milliroentgen per hour around the hypocenter. The highest intensity within this area was about 0.1 milliroentgen per hour.

6.2.2 Radioactivity Downwind of the Cities.

As the radioactive cloud was borne downwind from the center of each city, rainshowers within the hour after the detonation caused some of the fission products and unfissioned residue of the bomb to be carried to earth in a manner similar to fallout. This "rainout" produced a small pattern of radioactivity to the west of Hiroshima, near the village of Takasu; and a somewhat larger area to the east of Nagasaki, in the vicinity of the Nishiyama Reservoir. Other areas of fallout were documented farther downwind of the Nishiyama rainout.

Figures 18 and 19 show the areas and intensities of residual radioactivity caused by the rainout. Of the four patterns of measurable residual radioactivity remaining in and around the two cities upon the arrival of the occupation troops, the most significant was in the vicinity of the Nishiyama Reservoir outside Nagasaki, indicated in figure 19. This area, outlined by the contour of x's, had a slightly greater radiation intensity than the other areas. Inside the contour, the intensity rose gradually to a high of about one milliroentgen per hour at the time of the troops' arrival. Outside the contour, the intensity fell to background levels very quickly in the reservoir area and in the direction of Nagasaki. Moreover, this pattern east of Nagasaki was the only one of the four that included slight levels of plutonium in the radioactive mixture. The terrain was, however, remote and rugged, characterized by steep slopes and heavy forests, with few trails or roads and even fewer buildings. The Japanese population was sparse, and there were no occupation forces and little need for military patrols in the area.

The small rainout pattern west of Hiroshima, shown by the oval of x's in figure 18, had an intensity of 0.03 milliroentgen per hour. The exception was the center of the oval, which registered a high of less than 0.05 milliroentgen per hour when the occupation troops reached this part of Japan.

By the time of the occupation, the intensity of the ground radioactivity caused by rainout had dropped to less than a thousandth of the intensity 1 hour after shot-time. The main reason for this was the rapid overall decay of fission products. For example, a given intensity of radioactivity 1 hour after a detonation (H+1) will decay to one-tenth its former level within the next 7 hours. Two days after the detonation, the radiation intensity would have dropped to about one-hundredth of its H+1 value. Two weeks after the detonation, the intensity would have decayed to about one-thousandth of its H+1 value.

The reduction of radioactivity was aided by heavy rains during autumn 1945 that washed away some of the residual radiation. Between the bombings and the start of the occupation, approximately 62 centimeters (24 inches) of rain fell in Hiroshima and 82 centimeters (32 inches) in Nagasaki. The heavy rainfall continued during the occupation, and by 1 November the cumulative total since the bombing was 91 centimeters (36 inches) in Hiroshima and 122 centimeters (48 inches) in Nagasaki.

6.3 OCCUPATION OF JAPAN.

The occupation of the western portion of Honshu Island (which contains Hiroshima), the southern Japanese islands of Kyushu (where Nagasaki is located), and Shikoku was the responsibility of the Sixth U.S. Army, consisting of the I and X Army Corps and the V Amphibious Corps (Marines). Each Corps had three divisions and supporting units. The occupation force for this portion of Japan totaled some 240,000 troops.

The mission of the occupation troops was to establish control of the home islands of Japan, ensure compliance with the surrender terms, and demilitarize the Japanse war machine. The duties did not include the "cleanup" of Hiroshima, Nagasaki, or any other areas, nor the rebuilding of Japan.

6.3.1 Hiroshima Occupation.

Two divisions, both part of X Corps of the Sixth Army, accomplished the occupation of the counties in the vicinity of Hiroshima:

- 41st Division, 7 October 1945 to December 1945
- 24th Division, December 1945 to 6 March 1946, when the U.S. occupation of Hiroshima came to an end.

Participating troops were not stationed in the city of Hiroshima, which had been almost totally destroyed by the bombing and subsequent fires. Units of the two divisions were billeted instead in the rehabilitated buildings, hotels, and private residences in Kaidaichi, about 8 kilometers southeast of the center of Hiroshima (well off the map in figure 18). Only one unit--"G" Company of the 2nd Battalion, 34th Infantry Regiment of the 24th Division--was stationed in the vicinity of Hiroshima. The company was quartered in Ujina, a small island just south of the city.

Units of the 186th Infantry Regiment, 41st Division, conducted reconnaissance patrols and other specific daily assignments throughout its area of responsibility, which included the city of Hiroshima. It is reasonable to assume that individuals of the regiment made occasional patrols into the destroyed area of the city and that individuals from nearby units of the 41st Division may have made brief sightseeing trips into the area. Radiation doses received by these participants and the other occupation troops are summarized in section 6.4.

6.3.2 Nagasaki Occupation.

As compared to the Hiroshima occupation, the occupation of Nagasaki involved many more troops, largely because the excellent harbor at Nagasaki had not been extensively mined, thus being immediately usable. Because the harbor near Hiroshima had been heavily mined, it could not be used for an extended period after the surrender. While the Hiroshima occupation primarily involved Army troops, the occupation of Nagasaki consisted mostly of Marine Corps units, with small supporting Navy and Army elements.

Responsibility for the Nagasaki area was assigned to the 2nd Marine Division, a unit of the V Amphibious Corps. During the first 3 months of the occupation, Division strength in Nagasaki is estimated at approximately 10,000 troops. Division strength averaged about 5,000 to 7,000 for the next 3 months, through February 1946, and 3,000 to 4,000 for the last 4 months of the occupation, through June 1946.

Three units of the 2nd Marine Division had key roles during various periods of the occupation, as indicated below:

- 2nd Regimental Combat Team (RCT), 23 September to early November 1945
  - The zone of occupation included the east side of the Nagasaki harbor and most of the nearby county east of the Urakami River.
- 6th RCT, 23 September to December 1945
  - The zone of occupation included the west side of the Nagasaki harbor and most of the nearby county west of the Urakami River.
- 10th Marine Regiment, November 1945 to June 1946, when the Marine Corps occupation of Nagasaki came to an end
  - The Regiment assumed the responsibilities first of the 2nd RCT upon its departure from Nagasaki and then of the 6th RCT.

Specific billet locations have not yet been identified for all division units, which also included the 8th RCT, a Headquarters Battalion, Service Troops, an Engineer Group, a Tank Battalion, an Observation Squadron, and some smaller organizations. It is known, however, that the 2nd RCT was billeted in the Kamigo barracks and the 6th RCT in the Oura barracks, both shown in figure 19. The other troops also were in areas well clear of the hypocenter, which was cordoned off by the 2nd and 6th RCTs upon their arrival in the area.

Section 6.4 summarizes doses for participating units of the 2nd Marine Division, for Navy personnel who transported the Marines to Nagasaki and evacuated some 9,000 Allied former POWs during 1 through 13 September 1945, and for another 1,100 Navy support personnel.

6.4 RADIATION DOSES.

Few world events have been as thoroughly documented at the time and as intensively and continuously studied since by as many different groups of scientists as the atomic bombings and related radiation exposures at Hiroshima and Nagasaki. Thus, the patterns of residual radiation are well understood. This understanding, with other information, provides a solid basis for radiation dose determination.

The extensive radiation measurements and soil sample analyses taken by numerous Japanese and U.S. scientists in the weeks following the bombings are still available. These results and subsequent radiation measurements and sampling have formed the basis for intensive research over the past 40 years by Japanese and U.S. scientists of every aspect of the bombings and the radiation after-effects. The Japanese Government and the U.S. National Academy of Sciences have stimulated, supported, and advanced this research.

Likewise, the history of the U.S. occupation of Japan is well documented in Army, Navy, and Marine Corps archives. It is known which units were present, when they arrived, where they were stationed, what their missions were, and when they left.

From the above data, detailed technical dose reconstructions have determined the maximum possible radiation doses that might have been received by any participant. Chapter 7, Radiation Dose Determination, addresses this process, explaining the "worst case" analysis used to identify the highest possible dose. Using all possible "worst case" assumptions, the maximum possible dose any participant might have received from external radiation, inhalation, and ingestion is less than one rem. This does not mean that any individual approached this exposure level. In fact, it is probable that the great majority of personnel assigned to the Hiroshima and Nagasaki occupation forces received negligible radiation exposures and that the highest dose received by anyone was a few tens of millirem.

This chapter has sketched a topic that has been detailed in many scientific studies, Government reports, and journalistic accounts. The following bibliography identifies a selection of these sources, which should be available through major public and university libraries.

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SECTION 7

RADIATION DOSE DETERMINATION

The preceding three chapters have summarized the atmospheric nuclear tests and operations, radiation safety at the nuclear tests, and the postwar occupation of Hiroshima and Nagasaki. This chapter focuses on radiation dose determination for DOD personnel exposed to ionizing radiation as a result of their participation in atmospheric nuclear weapons testing or the postwar occupation of Hiroshima and Nagasaki. The narrative outlines general procedures, the identification of unit locations and activities, the use of film badge doses, statistical methods for dose determination, and the reconstruction of radiation doses.

7.1 PROCEDURE.

The primary procedure used by Nuclear Test Personnel Review (NTPR) researchers to determine the radiation doses of exposed individuals was through the film badge. Film badge dosimeters were generally issued to scientific personnel, both military and civilian, to personnel expected to be exposed to significant amounts of radiation, and to representative personnel, if not all personnel, in troop and naval units with common activities and relationships to the radiological environment.

Before using a film badge reading for dose determination, researchers had to ascertain that the badged period covered the entire period of exposure. Second, if representative badging was used, they had to determine that the activities--locations, times, protection--of the badged personnel adequately represented the activities of the group as a whole, in order that all personnel in the group could be judged to have received the dose(s) of the representative badge(s).

If a large number of personnel in an exposed group were badged, a statistical examination of film badge doses could be used to determine the mean dose, the variance, and the confidence limits. An estimated dose, equal to a high (usually 95 percent) probability that the actual exposure did not exceed the estimate, could then be assigned to unbadged personnel.

When dose data were not available or incomplete, or when there was reason to believe that the data did not adequately characterize the actual exposure, alternative approaches were used as circumstances warranted. All approaches had in common the investigation of individual or group activities and their relationship to the radiological environment. First, if it was apparent that personnel were not present in the radiological environment and had no other potential for exposure, then the assigned dose was zero. Second, if some members of a group had film badge readings and others did not--and if all members had a common relationship with the radiological environment--then doses for unbadged personnel could be statistically calculated. Third, where sufficient badge readings or a common relationship to the radiological environment did not exist, dose reconstruction was performed. This involved correlating a unit's or individual's activities with the quantitatively determined radiological environment.

The three approaches are summarized as follows:

1. Activities of an individual or his unit were researched for the period of participation in an atmospheric nuclear test. Unit locations and movements were related to areas of radiation. If personnel were far distant from the nuclear detonation(s), did not experience fallout or enter a fallout area, and did not come in contact with radioactive samples or contaminated objects, they were judged to have received no dose.

2. Film badge data from badged personnel may have been used to estimate individual doses for unbadged personnel, provided that the group of badged participants had common characteristics and potential similar to the unbadged personnel for radiation exposure. Then, using proven statistical methods, an estimated dose equal to 95-percent probability that the actual exposure did not exceed such estimate was assigned to unbadged personnel. This practice ensured that unbadged personnel were assigned doses that were considerably higher than the average or mean dose of the group.

3. Dose reconstruction was performed if film badge data were unavailable for all or part of the period of radiation exposure, if film badge data were partially available but could not be used statistically for calculations, if atypical activities were indicated for specific individuals, or if other types of radiation exposures were indicated. In dose reconstruction, the conditions of exposure were reconstructed analytically to determine the radiation dose. Such reconstruction was not a new concept; it is standard scientific practice used by health physicists when the circumstances of a radiation exposure require investigation. The underlying method was in each case the

> same. The radiation environment was characterized in time and space, as were the activities and geometrical position of the individual. The rate at which radiation was accrued was determined throughout the time of exposure, from which the total dose was integrated.
>
> An uncertainty analysis of the reconstruction provided a calculated mean dose with confidence limits. The specific method used in a dose reconstruction depended on what type of data were available to provide the required characterizations, as well as the nature of the radiation environment. The radiation environment was not limited to the gamma radiation that would have been measured by a film badge, but also included neutron radiation for personnel sufficiently close to a nuclear detonation, as well as alpha and beta radiation (internally) for personnel whose activities indicated the possibility of the inhalation or ingestion of radioactive particles.

Section 7.5, Reconstruction of Radiation Doses, provides detail on approach 3.

7.2 UNIT LOCATIONS AND ACTIVITIES.

To determine the precise locations and activities of units and individuals that could have been exposed to the radiological environment, extensive use was made of historical records and reports, augmented by personal interviews where necessary to fill gaps in the archival material. The result was a profile of activities for each definable group or individual. The locations and activities of military units, whose operations were closely monitored and controlled by radiological safety personnel, were usually well defined. The same was true for observers, who were restricted to specific locations both during and after the nuclear bursts (as described in reference 1, for example). Ships' locations and courses, with times, were usually known with a high degree of precision from deck logs. Aircraft tracks and altitudes were also usually well defined. Personnel engaged in scientific experiments often kept logs of their activities, noting times, locations, members of the party or crew, and unusual circumstances. Moreover, the locations of their experiments were almost always a matter of record, and the schedules of their early reentry times were often documented.

Where the records were insufficiently complete for the degree of precision required to determine radiation exposure, participant comments were used and reasonable judgments were made to further the analysis, such as was done for reference 2. In every case, both the distance from the detonation and the movement of the unit or individual with respect to the radiological hazards were determined. Careful consideration was given to possible or potential contact with contaminated objects. Activities were described in sufficient detail to permit assessment of the dose due to inhalation or ingestion of contaminated material, such as dust, debris, or food. For example, maneuver troops who crawled in radioactive areas, or who conducted helicopter operations in such areas, were afforded extensive analysis of their potential for inhaling radioactive dust that, when metabolized in the body, could have resulted in doses to internal organs over periods of several years. When there was a reasonable possibility that a given activity or set of circumstances could have existed for the unit, the benefit of the doubt was given. Possible variations in the activities, as well as possible and reasonable individual deviations from group activities, with respect to both time and location, were considered in the uncertainty analysis of the radiation dose calculations described in section 7.5.

7.3 FILM BADGE DOSES.

Before film badge readings could be used to characterize the radiation dose to a group or to an individual, it was first determined, primarily through analysis of the activities involved, that the badge readings represented the entire period of exposure. If they did not, or there was reason to believe that the badge(s) did not fully represent the entire conditions of exposure, alternative methods, such as statistical assignment or dose reconstruction, were pursued. This was obviously required in cases of exposure to initial radiation where neutrons were emitted from the burst, or in instances where inhalation or ingestion or radioactive particles was an issue. Neither of these types of exposure would have been recorded on a film badge.

7.4 STATISTICAL METHODS OF DOSE DETERMINATION.

To use badge readings to estimate the radiation doses to unbadged personnel, a group of participants was first identified that had common activity characteristics and a similar potential for exposure to radiation; that is, individuals must have been doing the same kind of work or activity and all members of the group must have had a common relationship to the radiological environment in terms of time after burst, location, duration of exposure, and behavior. Identification of these groups was based upon research of historical records, technical reports, or correspondence. For this purpose, a military or naval unit may, therefore, have consisted of several groups, or several units may have comprised a single group. This method was useful for personnel whose activities were confined to a ship and in situations where such activities could be assigned to the entire group under consideration.

Using proven statistical methods, the badge data for each group were examined to determine if they adequately reflected the entire group and were therefore valid for use in statistical calculations, or if the badge data indicated, by such characteristics as a bimodal distribution, that the group should have been subdivided into smaller groups where the distribution of readings was more normal. Only when the group data met the above tests were the mean dose, variance, and confidence limits used for assigning doses to unbadged personnel. When using this method, an estimated dose equal to 95 percent probability that the actual exposure did not exceed the estimate was then assigned to unbadged personnel. This high-sided, but statistically sound, procedure ensured that the assigned doses were much higher than the average or mean for the badged group.

7.5 RECONSTRUCTION OF RADIATION DOSES.

The general methodology for dose reconstruction consisted of characterizing the radiation environments to which participants, through all relevant activities, were exposed. The environments, both initial and residual radiation, were correlated with the activities of participants to determine accrued doses due to initial radiation, residual radiation, and/or inhaled/ingested radioactive material (3; 4). Because of the variety of activities, times, geometries, shielding, and weapon characteristics, as well as the normal spread in the available data pertaining to the radiation environment, an uncertainty analysis was performed. This analysis quantified the uncertainties due to time and space variations, group size and available data. An automated (computer-assisted) procedure was often used to facilitate handling the large amounts of data and the dose integration, and to investigate the sensitivity to variations in the values of parameters used. The results of the calculations were then compared with film badge data as they applied to the specific period of the film badges and to the comparable activities of the exposed personnel, in order to validate the procedure and to identify personnel activities that could have led to atypical doses.

Radiation dose from neutrons and dose commitments due to inhaled or ingested radioactive material were not detected by film badges (3; 4). Where required, these values were calculated and recorded separately.

7.5.1 Characterization of the Radiological Environment.

This process described and defined the radiological conditions as a function of time for all locations of concern, that is, where personnel were positioned or where their activities took place. The radiation environment was divided into the two standard categories: initial radiation and residual radiation.

The initial radiation environment resulted from several types of gamma and neutron emissions. Prompt neutrons and gamma radiation were emitted at the time of detonation, while delayed neutrons and fission-product gamma from the decay of radioactive products in the fireball continued to be emitted as the fireball rose. In contrast to these essentially point sources of radiation, there was gamma radiation from neutron interactions with air and soil, generated within a fraction of a second (5). Because of the complexity of these radiation sources and their varied interaction properties with air and soil, it was necessary to obtain solutions of the Boltzmann radiation transport equation (6). The radiation environment thus derived included the effects of shot-specific parameters, such as weapon design and yield, neutron and gamma output, source and target geometry, and atmospheric conditions. The calculated neutron and gamma radiation environments were checked for consistency with existing measured data. In those few cases displaying significant discrepancies that could not be resolved, an environment based on extrapolation of the data was used if it led to a larger calculated dose, such as was done for reference 1.

The residual radiation environment was divided into two general components: the neutron-activated material that emitted, over a period of time, beta and gamma radiation; and radioactive debris from the fission reaction or from unfissioned materials that emitted alpha, beta, and gamma radiation (5). Because residual radiation decayed or diminished, the characterization of the residual environment was defined by the radiation intensity as a function of type and time. Radiological survey data were used to determine specific intensities at times of personnel exposure. Interpolation and extrapolation were based on known decay characteristics of the individual materials that comprised the residual contamination (1; 3). In those rare cases where insufficient radiation data existed to adequately define the residual environment, source data were obtained from the appropriate weapon design laboratory and applied in standard radiation transport codes (7; 8; 9) to determine the initial radiation at specific distances from the burst. This radiation, together with material composition and characteristics, led to a description of the neutron-activated field for each location and time of interest. In all cases, observed data, as obtained at the time of the operation, were used to calibrate the calculations.

7.5.2 Activities of Participants.

This part of the process was precisely the same as that described in section 7.2. It was important that this step be carefully accomplished in order to define unique groups for which the radiation exposure was essentially common. Possible and reasonable variations in group activities, as well as individual deviations from those of the group as a whole, with respect to both time and location, were considered in each uncertainty analysis, described in section 7.5.4.

7.5.3 Calculation of Radiation Dose.

The initial radiation doses to close-in personnel (normally positioned in trenches at the time of the detonation) were calculated from the above-ground environment by simulating the radiation transport into the trenches. Various calculational approaches (7; 10), standard in health physics, were employed to relate in-trench to above-trench doses for each source of radiation. Detailed modeling of the human body in appropriate postures in the trench was performed to calculate not only the gamma dose that would have been recorded on a film badge, but also the maximum neutron dose (11). The neutron, neutron-generated gamma, and prompt gamma doses were accrued during such a short time interval that the posture in a trench could not have been altered significantly during this exposure. The fission-product gamma dose, however, was delivered over a period of many seconds (5). Therefore, the possibility of individual reorientation (e.g., standing up to observe the rising fireball) in the trench was considered (1; 12).

The calculation of the dose from residual radiation followed from the characterized radiation environment and personnel activities. Because radiation intensities were calculated for a field (i.e., in two spatial dimensions) and in time, the radiation intensity was determinable for each increment of personnel activity regardless of direction or at what time (1; 3). The dose from exposure to a radiation field was obtained by summing the contribution (product of intensity and time) to dose at each step. The dose calculated from the radiation field did not reflect the shielding of the film badge afforded by the human body. This shielding was determined for appropriate body positions by the solution of radiation transport equations as applied to a radiation field (3). Conversion factors were used to arrive at a calculated film badge dose, which not only facilitated comparison with actual film badge date, but also served as a substitute for any unavailable film badge reading.

The calculation of the dose from inhaled or ingested radioactivity primarily involved the determination of what radioisotopes entered the body in what quantity. Published conversion factors (13; 14) were then applied to these data to arrive at the radiation dose and future dose commitments to selected internal organs, such as bone marrow, lungs, and thyroid. Inhalation or ingestion of radioactive material was calculated from the radioactive environment and the processes of making these materials inhalable or ingestible. Activities and processes that caused material to become airborne (such as wind, traffic, or decontamination) were used with empirical data (15; 16) on particle lofting to determine airborne concentrations under specific circumstances. Volumetric breathing rates and durations of exposure were used to calculate the total material intake. Data on time-dependent weapon debris isotopic composition, and the above-mentioned conversion factors, were used to calculate the dose commitment to the body and to specific body organs (4; 17).

7.5.4 Uncertainty Analysis.

Because of the uncertainties associated with the radiological data or the calculations used in the absence of data, as well as the uncertainties with respect to personnel activities, confidence limits were determined where possible for group dose calculations. The uncertainty analysis quantified the errors in available data or in the model used in the absence of data. Confidence limits were based on the uncertainty of all relevant input parameters; thus, they have varied with the quality of the input data. The possible range of doses due to the size of the exposure group being examined were also considered. Typical sources of error have included orientation of the weapons, specific weapon yields, instrument error, fallout intensity data, time(s) at which data were obtained, fallout decay rate, route of personnel movements, and arrival/stay times for specific activities. References 1 and 3 discuss these in detail.

7.5.5 Comparison with Film Badge Records.

When this reconstruction methodology was first developed in 1978 and 1979, the calculations of gamma dose were compared with film badge records for two military units at Exercise Desert Rock VIII, Task Force WARRIOR and Task Force BIG BANG, both of which were involved, either directly or indirectly, in Shot SMOKY, Operation PLUMBBOB. Where all parameters relating to exposure were identified, direct comparison of gamma dose calculations with actual film badge readings was possible. The comparisons of actual and calculated doses were remarkably good, and the resultant correlations provided high confidence in the reconstruction methodology. References 3 and 4 illustrate these comparisons.

Film badge data may have been, in some cases, unrepresentative of the total exposure of a given individual or group. Nevertheless, such information has proved extremely useful for direct comparison of incremental doses for specific periods, e.g., validating the calculations for the remaining, unbadged periods of exposure. Moreover, a wide distribution of film badge data has often led to more definitive personnel or activity groupings for dose calculations and to further investigation of the reason(s) for such distribution. Reference 3 describes such distribution and subsequent investigation.

In no cases, however, were film badge data used in the dose calculations; rather, they have been and continue to be used solely for comparison with and validation of the calculations. In virtually all cases, comparison has been favorable and within the confidence limits established by the uncertainty analysis of each calculation.

7.6 RESULTS OF DOSE RECONSTRUCTIONS.

Dose reconstructions have been completed for all operations for which there is no film badge dosimetry and there was a reasonably high potential for significant radiation exposure to large groups or units, such as ship crews or maneuver troop units. These reconstructed doses provide, in the absence of dosimetry, the readings of what would have been recorded on film badges, had they been worn. Because film badges did not record neutron doses or doses from inhaled or ingested radioactive contaminants, doses for these types of exposures, being much less prominent from a numbers standpoint, are being reconstructed separately.

7.7 REVIEW OF RECONSTRUCTION METHODOLOGY.

The dose reconstruction methodology and processes have been reviewed, in whole and in part, by several authorities over the entire term of the NTPR program. The first NTPR report dealing with dose reconstruction, that for Task Force WARRIOR at Shot SMOKY (3), was critically reviewed in 1979 by nationally recognized radiation experts from scientific laboratories, as well as by the Office of Technology Assessment (at the request of Senator Cranston), and the Medical Follow-up Agency of the National Research Council, National Academy of Sciences. These reviews provided the confidence to finalize the methodology and to adapt it to many other exposure scenarios. Other dose reconstructions were subsequently reviewed by committees appointed by the National Academy of Sciences. One such review was conducted in 1980-81 of the Hiroshima-Nagasaki dose reconstructions (18, 19), and another review, that of the entire dose reconstruction effort, was conducted in 1984-85 (20). In both instances, the reviews judged the dose reconstruction methodology and processes to have sound scientific merit. No major deficiencies were noted that would reflect unfavorably on the technical aspects of the dose reconstruction methodology or on the radiation doses calculated therefrom.

Recently, as a result of concerns over the doses received by participants at CROSSROADS, Senator Cranston asked the General Accounting Office to investigate alleged improprieties or deficiencies associated with CROSSROADS records, dosimetry, and dose reconstructions. The investigation, completed in 1985 (21), did not assess the methodology used to calculate radiation doses, but nonetheless concluded that film badge dosimetry, personnel decontamination procedures, and contaminant ingestion could have led in some instances to higher doses than were reported. Regardless, even if doses were higher as alleged, they would not have exceeded established standards for radiation exposure.

SECTION 7

REFERENCE LIST

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See Availability Information page in Appendix E.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.

REFERENCE LIST (Continued)

13. "Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake." Wash., DC.: Nuclear Regulatory Commission. NUREG-0172. Nov 77. 108 p. (A06)PB-275 348.*

14. Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities. 2 vols. Oak Ridge, TN: Oak Ridge National Laboratories. ORNL/NUREG/TM-190. Jun 78 and Nov 79. (A14)NUREG/CR-0150* and (A22) NUREG/CR-0150-V-2.*

15. "The Resuspension of Particulate Matter from Surfaces." K. Stewart. (In: Proceedings of a Symposium on Surface Contamination, NY.: Pergamon Press, Jun 64.)

16. "Resuspension and Redistribution of Plutonium in Soils." L.R. Anspaugh et al. Health Physics, Vol 29, #4 (Oct 75). p. 571-582.

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19. "Multiple Myeloma among Hiroshima/Nagasaki Veterans." National Research Council, Medical Follow-Up Agency. Wash., DC.: Jun 83. 13 p.

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See Availability Information page in Appendix E.
*Available from NTIS; price code and order number appear before the asterisk.

SECTION 8

HEALTH EFFECTS OF IONIZING RADIATION AND MEDICAL FOLLOWUP STUDIES OF VETERANS

This chapter outlines what is known about the health effects of ionizing radiation. It then summarizes the studies conducted by several agencies to ascertain if such effects exist among veterans who participated in U.S. atmospheric nuclear weapons tests and in the postwar occupation of Hiroshima and Nagasaki, Japan.

8.1 HEALTH EFFECTS OF IONIZING RADIATION.

The biological effects resulting from exposure to ionizing radiation can be grouped into two general categories, **acute** (quickly observed) and **delayed**.

Examples of acute effects are erythemia or reddening of the skin, blood changes, vomiting, loss of hair (epilation), and even death in the extreme case. Before such effects can be observed, a certain minimum radiation dose, or threshold, must be exceeded. The magnitude of the effect and normally the speed at which it occurs increase with the size of the radiation dose. Except in fatal cases, most acute effects are not permanent. For example, blood will return to normal, hair will grow back, and skin burns will heal, although some scarring and pigmentation loss may occur.

Acute effects and their threshold doses are well known. The table on the next page indicates the acute effects of whole-body exposure to various levels of ionizing radiation (1). Observable acute effects do not occur at radiation doses below approximately 25 rem, as noted in the table. Better than 99 percent of all doses received by nuclear test participants were well below this threshold; therefore, such effects were not evident.

Acute Effects of Exposure to Ionizing Radiation

Dose (rem)	Effect
25-50	Blood changes. For example, white blood cells begin to disappear. Temporary sterility in men.
75	Vomiting in 10 percent of those exposed.
200	Depression or ablation of bone marrow. Nausea and vomiting within hours. Epilation (loss of hair) within 2 or 3 weeks.
300	Erythema (reddening of the skin).
450	Lethal dose for 50 percent of those exposed. Death within 30 days.
1000	Loss of intestinal wall. Death within 1 or 2 weeks.
2000	Unconscious within minutes, death within a few hours.

Examples of delayed effects include cataracts, several forms of cancer, and genetic disorders in offspring. Cataracts appear after a latency period of several years and require a threshold dose of at least 200 rem. Genetic effects have been demonstrated only in animal studies; they have not been observed in humans. For example, data collected on more than 30,000 offspring of people irradiated at Hiroshima and Nagasaki did not reveal statistically significant increases in stillbirths, neonatal deaths, birth weight, or congenital malformations (2; 3).

According to current medical knowledge, no threshold dose is required for cancer induction. Since cancer occurs naturally in the general population and cannot be distinguished from radiation-induced disease, the problem of risk assessment, especially at low doses, is complex. The only way to determine the magnitude of the cancer risk is to study large groups of exposed personnel and compare their cancer incidence with that of a similar, unexposed group.

Numerous national and international authorities have conducted such studies. It is beyond the scope of this history to discuss these studies in any detail; however, some relevant findings are summarized below (1):

Risk Estimates for Fatal Cancers from Gamma Radiation

Source*	Cancer deaths per million man-rem
BEIR I (1972)	115-621
ICRP (1977)	125
UNSCEAR (1977)	100
BEIR III (1980)	67-226**

The risk estimates presented above are in terms of cancer deaths per million man-rem; UNSCEAR, for example, predicted 100 deaths for a population of 1 million persons receiving a whole-body radiation dose of 1.0 rem. The UNSCEAR data can be translated to one fatal cancer among 10,000 persons receiving a dose of 1.0 rem. The latest findings published by the NAS BEIR III Committee predict slightly over two radiation-induced fatal cancers among a population of 10,000 so exposed. According to current cancer risk estimates, approximately 1,600 fatal cancers occur naturally in a population of 10,000 persons (16 percent). Therefore, one or two additional cases would fall within the random variation of such data, thereby making it virtually impossible to detect an increased incidence rate among a population of 10,000 receiving a dose of 1.0 rem. Obviously a much higher dose or larger group would be needed to detect an increase with any statistical significance (1).

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*The BEIR report was prepared by the National Academy of Sciences (NAS) Committee on the Biological Effects of Ionizing Radiation. ICRP is the International Committee on Radiological Protection, and UNSCEAR is the United Nations Scientific Committee on the Effects of Atomic Radiation.

**The number cited is the majority opinion. One dissenting member estimated cancer deaths at the 158-501, and another dissenting member estimated 10-28 deaths per million man rem.

When specific forms of cancer, such as leukemia, are considered, the natural incidence rate is lower. Thus, small increases in the incidence become more significant. Several studies have been made to determine whether there is an increased incidence of certain cancers among various groups of veterans who participated in nuclear tests. The following sections briefly summarize these efforts.

8.2 CENTERS FOR DISEASE CONTROL STUDIES.

The Centers for Disease Control (CDC) was the first organization to study military participants in the atmospheric nuclear weapons tests from a health point of view. In the latter part of 1976, CDC learned of a veteran who related his acute myelocytic leukemia to radiation exposure he claimed to have received during participation at Shot SMOKY, a 44-kiloton detonation that took place on 31 August 1957 as part of Operation PLUMBBOB. Extensive publicity regarding this case prompted the CDC to initiate a study to determine if there was an excess incidence of leukemia among the nuclear test participants that might be attributable to radiation exposure. Plans were to focus on the military participants at Shot SMOKY.

The identification of a SMOKY cohort proved more difficult than expected. The index case was a member of Task Force BIG BANG, an Army unit selected to study how well military personnel who had never witnessed a nuclear explosion would perform various military tasks after such an experience. Because of an unexpected shift in wind direction, the exercise planned for Task Force BIG BANG had to be postponed. As a result, the unit observed Shot SMOKY from the press area approximately 30 kilometers away. After observing Shot GALILEO, detonated on 2 September 1957, the unit conducted its exercise in an area contaminated by 2-day-old SMOKY fallout in addition to fallout from at least three previous PLUMBBOB shots. Another military maneuver was conducted in conjunction with Shot SMOKY. Task Force WARRIOR, a reinforced infantry company from the 1st Battle Group, 12th Infantry, 4th Infantry Division, performed exercises upwind of the SMOKY ground zero shortly after the shot. The area was essentially free of SMOKY fallout but was contaminated by fallout from previous PLUMBBOB shots.

To complicate matters further, there was no central listing of participants by name. A study cohort was finally identified from research by the Armed Forces Radiobiology Research Institute (AFRRI), an element of the Defense Nuclear Agency. The list named 3,153 military personnel* who had been issued film badges at the Nevada Test Site (NTS) for the period that included 31 August 1957, the date of Shot SMOKY. Seventy-one names were added from other sources, thereby making a total cohort of 3,224 individuals. This number of individuals was used in the study.

Several sources were then explored to identify the cases of leukemia and other cancers among this cohort. Four leukemia cases were identified from a list of more than 3,000 individuals who made inquiries regarding the publicity surrounding the index case. Of these personnel, 447 had been at the NTS on 31 August 1957. The AFRRI list was also compared with various clinical files, including those of the Armed Forces Institute of Pathology (AFIP), the Veterans Administration (VA) death benefit file, and personnel records at the National Personnel Records Center. Four more cases were identified from these records, which made a total of nine (including the index case).

Each case was confirmed by CDC, and the total exceeded the expected incidence of 3.5 leukemia cases in this cohort. The expected incidence was calculated by applying age- and sex-specific incidence rates published by the National Cancer Institute to the person-years accumulated by the SMOKY cohort from 1957 through mid-1977. Eight of the nine cases had died by the time of the study. This exceeded the expected mortality of 2.9 calculated from U.S. rates for the 1970s. Both comparisons were considered statistically significant, even if two of the cases that could be questioned with regard to inclusion in the cohort were dropped.

Radiation exposure was considered as a possible cause of this increased incidence. The available dosimetry (film badge results) and radiological analyses of tissue from two patients did not, however, support this hypothesis. Therefore, CDC tentatively concluded that if the apparent excess of leukemia were not a chance occurrence, the SMOKY participants may have received higher radiation doses than supposed (perhaps from neutrons or inhaled radioactive material not detected by film badges) or radiation was more carcinogenic at low doses than previously assumed.

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*Primarily U.S. Army personnel who were assigned to Exercise Desert Rock and wore film badges provided by the U.S. Army Signal Depot, Lexington, KY.

The CDC published a preliminary report of these findings in the 3 October 1980 edition of the Journal of the American Medical Association (4). The CDC continued to study the incidence of all forms of cancer as well as causes of death among the cohort, which was eventually refined to 3,217 veterans. Disease incidence and mortality data were collected through 1979 on over 95 percent of the cohort.

The followup study identified a total of 112 cancer cases, which is below the expected number of 117.5 cases. The incidence of some specific cancer types was slightly higher than expected, but the increase was not considered statistically significant with the exception of leukemia (one additional case was identified). Cancers of the digestive system, respiratory, genital, and urinary systems occurred less often than expected. No cancers of the bone/joints, soft tissue, endocrine system, or multiple myeloma were found.

With regard to mortality, the cohort had considerably fewer total deaths than expected. The number of deaths increased in only three categories--infectious and parasitic diseases, accidents, and killed in action. Deaths from individual types of cancer exceeded the norm in five categories--leukemia, brain and nervous system, eye and orbit, genital system, and skin melanoma. Again, only the increased incidence of leukemia deaths was found statistically significant.

An analysis of the film badge dosimetry available for the cohort showed that, in general, radiation doses were well within current occupational exposure standards. The analysis also showed that the mean dose received by participants engaged in the military maneuver was higher than the mean dose received by support units. However, the frequency of cancer was higher among the participants assigned to support units. Assuming that the dosimetry is correct, at least in a relative sense, the opposite would be expected if radiation were the cause.

The findings, published in the 5 August 1983 issue of the Journal of the Americal Medical Association, indicated several biases that affected the study. The authors noted, for example, that the index case was included in the sample and that one of the leukemia cases was for a deceased Air National Guard pilot whose presence at SMOKY was questionable (5).

In summary, the CDC 1983 study revealed an increase in the incidence of leukemia and resulting deaths among a group of nuclear test participants issued film badges at the NTS for the period covering the date of Shot SMOKY. The incidence of other forms of cancer, other selected diseases, and the overall mortality among the cohort was typical of that for the general population. The conclusion was as follows: "Although uncertainty remains about the exact amount of radiation exposure, the lack of a significant increase after 22 years in either the incidence of or the mortality from any other cancer and the apparent lack of a dose effect by units lead to the consideration that the leukemia findings may be attributable either to chance, to factors other than radiation, or to some combination of risk factors possibly including radiation" (5).

8.3 ARGONNE NATIONAL LABORATORY STUDY.

The CDC study discussed above concluded that the increased incidence of leukemia among the "SMOKY" cohort may be attributable to chance or the result of an unknown combination of factors. A possible factor was that the radiation doses might have been higher than reported since only external gamma radiation exposures were considered. One hypothesis was that significant internal doses resulted from inhalation or ingestion of radioactive material.

As a check, a group of 19 veterans was selected from the SMOKY cohort by the CDC to be sent to the Argonne National Laboratory (ANL) for special testing. The group was chosen on the basis of high film badge readings and/or potential for internal exposure. None of the group exhibited any clinical signs of radiogenic malady. Three members of the group, however, chose not to participate in the study.

The remaining 16 veterans visited ANL during 1979, when they were interviewed regarding their participation (exposure scenario) and checked for evidence of residual internal radioactivity that might be attributable to such participation. Whole-body and thorax gamma-ray counts were made looking specifically for Cesium-137, a fairly long-lived fission product that distributes throughout the body after intake. Using different instruments, similar measurements were made for Plutonium-239 in the thorax and skull. While at ANL, the veterans also provided 24-hour urine specimens that were analyzed for Plutonium-239 and Strontium-90.

None of the tests revealed internal radioactivity in excess of that found in the general population. Thus, the authors concluded that they had "no evidence that these subjects received any significant internal dose from their participation in the SMOKY weapon test" (6).

8.4 NATIONAL RESEARCH COUNCIL STUDIES.

The NAS National Research Council (NRC) concluded two medical studies pertinent to this report: Studies of Participants in Nuclear Tests (1985), known as the Mortality Study, and "Multiple Myeloma among Hiroshima/Nagasaki Veterans" (1983). This section discusses the procedures and findings of each study.

8.4.1 Mortality Study.

Preliminary reports by the CDC in 1979 that a statistically significant increase in leukemia incidence was occurring in the "SMOKY cohort" caused considerable concern. The Defense Nuclear Agency (DNA) requested the Medical Follow-up Agency of the NAS National Research Council (NRC), an independent non-Government agency, to undertake a study of this issue. The details of the study were left to the NRC. Funded by both DNA and DOE, the effort was to determine whether participants at nuclear tests other than SMOKY were also experiencing an increased incidence of leukemia, other cancers, or any other fatal disease. The Medical Follow-up Agency chose a study cohort of about one quarter of the test participants in the five series identified below:

Series	Year	Location	No. of Detonations
GREENHOUSE	1951	PPG*	4
UPSHOT KNOTHOLE	1953	NTS**	11
CASTLE	1954	PPG	6
REDWING	1956	PPG	17
PLUMBBOB	1957	NTS	24

*Pacific Proving Ground
**Nevada Test Site

As for the CDC study of Shot SMOKY, complete rosters of participants in these series did not exist. The Nuclear Test Personnel Review (NTPR) teams, using such sources as ship deck logs, unit morning reports, special orders, after-action reports, and film badge dosimetry logs, identified by name a total of 49,148 participants by March 1983. This list was selected as the cohort for the NRC study. Only persons identified from valid records were included in the study; self-reported participants were not accepted by NAS.

Because of the large number of participants, tracing each individual's health status, in particular for incidence of disease, was considered impractical for both technical and financial reasons. It was decided, therefore, to limit the study to mortality and to use records maintained by the Veterans Administration. A mortality study would indicate any unusual incidence and would tell if a morbidity study was warranted.

Names and other identification, such as social security numbers, were submitted to the VA Beneficiary Identification and Records Locator Subsystem (BIRLS) to ascertain who had died through 1982 and the location of their VA records. Death certificates for those confirmed dead by the BIRLS were ordered from the VA regional offices. No record existed in the BIRLS for many of the names submitted. These names were directed to the National Personnel Records Center (NPRC) in St. Louis, Missouri, for further research using such files as the VA Master Index.

The records search confirmed a total of 5,113 deaths from all causes. This number represents 11.1 percent of the study cohort, and when compared to U.S. mortality rates is 83.5 percent of the number of deaths that normally would be expected.

Mortality in this cohort from accidents, acts of war, and other external causes was 6 percent higher than that expected, using U.S. population rates. On the other hand, the 1,046 cancer (including leukemia) deaths were only 84 percent of the number expected, and the 2,579 deaths from other diseases were only 69 percent of expectation. Similar results emerged when each test series was examined separately. However, a statistically significant excess number of deaths from prostate cancer (not thought susceptible to causation by radiation) was found among the Operation REDWING participants.

As a check on the methodology used in the study, the SMOKY participants at Operation PLUMBBOB were subjected to the same mortality ascertainment procedures used for participants at other shots and test series. The size of the cohort increased to 3,554 participants, slightly higher than that of the CDC study, and 10 leukemia deaths were found. This incidence, 2.5 times the expected number (3.97), is considered statistically significant. No cancers other than leukemia were found in excess, and the total number of cancer deaths (67) was less than the number expected (83.8) using U.S. population rates. These results parallel those reported earlier by CDC and lend credence to the methodology pursued in the NRC study.

The following conclusions, quoted from the published findings, resulted from the study (7):

1. The finding by Caldwell et al. that an excessive number of cases of leukemia has occurred among former participants at Shot SMOKY of the PLUMBBOB series was confirmed.
2. No evidence was found that leukemia mortality was increased among participants at PLUMBBOB tests other than SMOKY or among participants at UPSHOT-KNOTHOLE, GREENHOUSE, CASTLE or REDWING.
3. Generally accepted estimates of the rate of excess leukemia induction per rem when applied to estimates made by DNA of the radiation doses to participants result in an expected increase of leukemias among SMOKY participants of less than 0.2 case. The observed excess

mortality from leukemia among these men, then, either was a chance aberration or argues that the mean radiation doses at SMOKY (but not at the other test series) were several times the doses recorded by the film badges that were used.

4. No evidence was found that any cancer other than leukemia occurred excessively among former SMOKY participants.

5. Mortality from cancer in all groups of participants was, in general, found to be less than the number expected at population death rates, and mortality from other disease was much less than expected, a consequence of selection for good health by the physical screening employed for active duty servicemen.

6. Although there were significant excesses of leukemia among SMOKY participants and of prostate cancer among REDWING participants, no form of cancer was found to be increased in more than one test series. Since many independent comparisons of cancer rates were made, the two "significant" excesses may well have resulted from chance.

7. The total body of evidence reviewed does not convincingly either affirm or deny that the higher than statistically expected incidence of leukemia among SMOKY participants (or of prostate cancer among REDWING participants) is the result of radiation exposure incident to the tests. However, when the data from all the tests are considered, there is no consistent or statistically significant evidence for an increase in leukemia or other malignant disease in nuclear test participants.

8.4.2 Study of Multiple Myeloma Among Hiroshima/Nagasaki Veterans.

The DNA Director requested the NRC to undertake the multiple myeloma study in response to allegations by various veteran groups that the disease was occurring with increased frequency among participants in the U.S. postwar occupation of Hiroshima and Nagasaki, Japan. The effort began with formation of a panel of experts from various medical and scientific disciplines. On 13 and 14 May 1981, a workshop was held at the National Academy of Sciences to review the available data in order to advise DNA concerning the feasibility and desirability of performing epidemiologic studies of the Hiroshima and Nagasaki occupation forces.

While invitations to participate were sent to a number of veteran organizations, only representatives of the Committee for U.S. Veterans of Hiroshima and Nagasaki and the National Veterans Law Center accepted. Representatives of the American Veterans Committee and the Disabled American Veterans were present as observers.

DNA representatives briefed the panel on the details of the occupation, such as the units involved, troop arrivals and departures, billet locations, and mission and assignments. Science Applications International Corporation, a DNA contractor, then provided a worst-case estimate of the radiation doses received by the occupation forces based on historical reports of occupation troop activities and radiological data taken directly from refereed journals and technical reports available to the panel. Staff members of the Radiation Effects Research Foundation and the National Cancer Institute also provided expert testimony. Representatives of the veterans group took part in the discussions following these presentations.

Based on the data presented at this workshop, the panel concluded the following, quoted from the report summarizing their meeting (8):

> 1. Scientifically sound studies of morbidity among military personnel who entered Hiroshima or Nagasaki soon after the bombings are impractical. Records of morbidity in this population are just not available, nor could they be assembled in any objective or systematic fashion.
>
> 2. Studies of mortality among these men are feasible. However, from a strictly scientific point of view, such studies appear to carry inordinate cost in relation to the potential benefit.
>
> 3. No study of the population in question could detect effects that would be predictable from existing knowledge of health hazards associated with radiation exposure.
>
> 4. The possibility that multiple myeloma is occurring in excess in these veterans, as has been alleged, should be explored. This should not at first involve a full-scale epidemiologic study. The number of confirmed cases of the disease in this population should first be determined, and an evaluation made as to whether this is excessive before any further studies are recommended.... Even if an excess number of cases of multiple myeloma is present in this population, it is unlikely to be attributable to ionizing radiation.

DNA requested that conclusion 4 be pursued. The NAS accordingly appointed a new panel tasked to investigate all alleged cases of multiple myeloma among the occupation troops, verify the diagnosis, and compare the number of verified cases with the number of cases that would be expected in a similar (unexposed) population.

Twenty-eight possible cases of multiple myeloma were identified from two lists of veterans who said they had served in Hiroshima or Nagasaki. DNA compiled one of the lists as part of its NTPR program. The other list was provided by the National Association of Atomic Veterans (NAAV), which had polled its membership of about 2,000. The DNA list contained 687 names, and the NAAV list approximately 500 names.

The NTPR Service teams and participating NAS staff members screened military records of the 28 veterans possibly having multiple myeloma. They eliminated nine of the veterans because their records did not confirm military assignments to Hiroshima or Nagasaki.

Clinical records were sought from the 19 remaining cases. The veteran or, if deceased, his next-of-kin was asked for permission to obtain his medical records (including X-rays and microscope slides) from the appropriate medical authority. Six more cases were eliminated, five of them because the veterans or next-of-kin did not respond to NAS inquiries and one because a physician did not respond to the request for medical records. Four cases were eliminated from the remaining 13 when further military record searches revealed that two of the personnel had not been assigned to Hiroshima or Nagasaki and the medical records of the other two made no reference to multiple myeloma.

The panel confirmed nine cases of multiple myeloma among the Hiroshima/Nagasaki veterans. Five of the cases had been assigned to the Nagasaki occupation; the other four were associated with Hiroshima. All cases were diagnosed between the ages of 51 and 61, the time when the disease normally appears.

On the basis of multiple myeloma incidence rates reported by the National Cancer Institute and assuming that at least 20,000 men were assigned to occupation duty at Nagasaki, the panel calculated that 9.5 cases of the disease would be expected by 1980 if all of the troops had been between the ages of 15 to 19 years at the time of the occupation. At least 18.2 cases would be expected if the ages had been between 20 and 24, and 29.2 cases would be expected if the ages had been between 25 and 29 in 1945. Similar figures were not calculated for Hiroshima since it is not possible to estimate the number of Service personnel who may have visited the city. (Occupation forces for the area were not billeted in Hiroshima proper.)

Since only nine cases were confirmed among the Hiroshima and Nagasaki occupation forces, the panel concluded that the incidence of multiple myeloma was no greater than that in the U.S. population. Their conclusion was qualified by the admission that it is quite possible that not every case had been identified (9).

8.5 PROPOSAL FOR VETERANS ADMINISTRATION STUDY.

The Veteran's Health Care Amendments of 1983 (Public Law 98-160) tasked the Administrator of Veterans' Affairs, in consultation with the Director of the Office of Technology Assessment (OTA), to:

> Provide for the conduct of epidemiological study of the long-term adverse health effects of exposure to ionizing radiation from the detonation of nuclear devices in connection with the test of such devices or in connection with the American occupation of Hiroshima and Nagasaki, Japan, during the period beginning on September 11, 1945, and ending on July 1, 1946, in persons who, while serving in the Armed Forces of the United States, were exposed to such radiation. Such study shall include, but not necessarily be limited to, a study of identifiable prevalent illnesses, including malignancies, in the persons exposed.

The law further states that the requirement to carry out the study will "cease to have effect as if repealed by law" if the VA Administrator, in consultation with the OTA Director, finds that such a study is not feasible.

In December 1984, the VA completed its proposed study plan, "VA Assessment of Veterans with Military Service at Sites of Temporarily Augmented Ionizing Radiation." A two-phase health assessment was proposed.

The first phase called for a questionnaire to be mailed to all veterans who participated in the Hiroshima/Nagasaki occupation or any of the U.S. continental or oceanic nuclear tests. The questionnaire would be designed primarily to collect information on physical health, particularly regarding cancer and other chronic disease, but it would also seek information on mental health and lifestyle factors. The same questionnaire would also be sent to a similar number of veterans who had no history of such participation. Results from the two groups, adjusted for age, occupation, smoking habits, and other influences, would be compared.

The second phase would include medical and physiological examinations of an unspecified number of veterans and the collection of data regarding possible congenital or genetic abnormalities in their children. The methodology for the analysis of this information was not addressed.

The VA plan was first reviewed by a panel of Government scientists, headed by Dr. Glyn Caldwell, who had authored the SMOKY study at CDC. The Caldwell review was then submitted to the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC). Both the Caldwell committee and CIRRPC concluded that the VA plan did not describe a feasible study since it would be impossible to detect the small excess of disease expected in a group of approximately 200,000 personnel exposed to the reported low levels of radiation.

The VA plan and the Caldwell/CIRRPC review were submitted to the Director of OTA for review in January 1985. OTA examined these documents and conducted its own independent review of the feasibility of the epidemiological study. The independent OTA study analyzed two strategies for assessing the health of these veterans. The first was similar to that proposed by the VA, that is to study approximately 200,000 participants in the nuclear tests. (The Hiroshima/Nagasaki occupation troops were excluded since the doses were so low that their inclusion would weaken rather than strengthen the power of the study.) The second strategy was to study approximately 1,400 veterans with measured or estimated doses greater than 5.0 rem. The power of each strategy to detect the expected excess of radiogenic cancers was calculated based on the radiation dose information available. These calculations were repeated for doses several times higher to account for possible understatement of reported dose.

The OTA concluded, as had the Caldwell committee and CIRRPC, that such "global" studies concerning the health of nuclear test veterans are not feasible. The agency did, however, suggest two more specific studies that could provide useful information (10):

1. Continue to follow (at 5-year intervals) the "SMOKY" cohort previously studied by the CDC/NRC. If the excess leukemia detected was simply a matter of chance, no excess of other radiogenic cancers would be expected.
2. Conduct a mortality study of the veterans who participated in Operation CROSSROADS pending the results of a General Accounting Office review of the radiation dose estimates.

In determining the feasibility and desirability of an epidemiological study or studies, the VA Advisory Board considered the recommendations of the Caldwell committee, CIRRPC, and OTA. It also reviewed commentary given in the following: the General Accounting Office (GAO) report Operation Crossroads: Personnel Radiation Exposure Estimates Should Be Improved (8 November 1985), discussed in section 7.7; the NAS report Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests (7 February 1986), discussed in section 7.7; and the hearing held by the Senate Committee on Veterans Affairs on 11 December 1985 regarding issues pertinent to possible radiation exposures received by CROSSROADS participants.

During February 1986, the VA Advisory Board listened to presentations by DNA, GAO, and NAS on dose determination for CROSSROADS participants. As a result of Board recommendations, VA decided that it would not participate in a mortality study of CROSSROADS veterans but that it would continue the followup of SMOKY personnel. The Administrator of Veterans' Affairs informed OTA of these decisions in April 1986.

OTA is reviewing the VA decisions and is considering a NAS proposal to conduct a mortality study of CROSSROADS personnel. In March 1986, DNA indicated to the Senate Committee on Veterans Affairs that it would be willing to provide part of the funding if OTA considered the study feasible and if Congress decided against appropriating funds specifically for the effort. A decision on this study is expected in late 1986.

* * * * *

The NTPR effort and related activities are not concluded. Further medical followup studies may well be conducted of the participants in the U.S. atmospheric nuclear weapons testing program. Veterans and other interested parties will continue to use the DNA toll-free line, request information concerning participation and dose, and file claims with VA. Anniversaries of the Hiroshima and Nagasaki bombings will periodically refocus national attention on veterans of the occupation, as well as on the atmospheric nuclear weapons tests.

The Defense Nuclear Agency, initiator and administrator of the Nuclear Test Personnel Review program, is prepared to respond to continuing requests for data. With the support of the NTPR teams, as well as DOE and the VA, the NTPR program has essentially realized its assigned tasks. In so doing, it has assembled and organized a body of information that should be useful for years to come.

SECTION 8

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APPENDIX A

CHRONOLOGY OF SELECTED EVENTS RELEVANT TO THE NTPR PROGRAM

Early 1977	Centers for Disease Control (CDC) identified a former participant in U.S. atmospheric nuclear weapons testing who had leukemia. CDC suspected an abnormal incidence of leukemia among participants in Shot SMOKY, conducted on 31 August 1957 as part of Operation PLUMBBOB.
6 May 1977	*Ad hoc* Department of Defense (DOD) committee met to formulate goals and an agenda for conducting a detailed review of troop participation in the atmospheric nuclear test program. The committee was chaired by the Director of the Defense Nuclear Agency's (DNA's) Armed Forces Radiobiology Research Institute (AFRRI) and included representatives from various Army organizations, such as the Office of the Surgeon General, Office of the Deputy Chief of Staff for Operations and Plans, and Office of the Chief of Public Affairs.
3 June 1977	DOD, Department of Energy (DOE), Reynolds Electrical & Engineering Company (REECo), and Los Alamos National Laboratory (LANL) representatives met at the DOE Nevada Operations Office (NVOO) in Las Vegas to determine the availability of information on personnel exposures to ionizing radiation during the atmospheric nuclear tests.
15 June 1977	AFRRI provided initial participant information to CDC concerning the Provisional Company, 82nd Airborne Division, which was one of the Army contingents that had been at Shot SMOKY.
3 November 1977	Interagency committee, involving DOD, DOE, the Veterans Administration (VA), and the U.S. Public Health Service, met to discuss the possible long-term health effects resulting from participation in atmospheric nuclear weapons testing. The attendees recommended that a major epidemiological study of test participants be undertaken under the direction of an independent scientific organization and that a central administrative unit be established within DOD to coordinate all related activities.
1 December 1977	Meeting convened by the Assistant Secretary of Health for Health Affairs to address the atmospheric nuclear weapons testing program and the possible relationship between participation in the program and an increased incidence of disease attributable to radiation exposure. Participants included representatives from the military services, Defense Nuclear Agency (DNA), DOE, VA, CDC, and National Research Council (NRC) of the National Academy of Sciences (NAS), as well as epidemiological consultants from Walter

	Reed Army Medical Center. Results of the meeting were decisions to solicit a formal proposal for a study of the atmospheric nuclear test participants from NRC and the unofficial assignment of DNA as the DOD executive agency for all matters pertaining to DOD personnel participation in the atmospheric nuclear test program.
January 1978	DOE began its research on the nuclear test participants with specific emphasis on identifying military personnel.
24-26 January and 14 February 1978	DNA representatives testified at a hearing held by the Subcommittee on Health and Environment of the House Subcommittee on Interstate and Foreign Commerce. They summarized DNA efforts to develop data on DOD participants in atmospheric nuclear weapons testing. DOE also testified regarding DOD participants and exposures.
28 January 1978	Assistant Secretary of Defense, Manpower, Reserve Affairs, and Logistics, officially designated the Defense Nuclear Agency as executive agent to develop information on DOD personnel participation in the U.S. atmospheric nuclear weapons tests.
9 February 1978	DNA initiated its nationwide toll-free call-in program for veterans of the atmospheric nuclear tests to report their participation.
13 February 1978	DNA initiated the NTPR program by a memorandum to the Secretaries of the Military Departments that established basic relationships and procedures.
4 April 1978	DOE hosted a meeting attended by representatives of the DOD NTPR, National Archives, REECo, LANL, NAS/NRC, and each DNA contractor organization. The agenda focused on methods for identifying and obtaining records pertaining to atmospheric nuclear weapons testing.
7 April 1978	VA issued Circular 10-78-69 authorizing physical examinations for nuclear test participants.
9 May 1978	The White House directed the Department of Health, Education, and Welfare (HEW) to coordinate a task force investigation concerning the health effects of exposure to ionizing radiation.
8 June 1978	DNA established the data elements to be developed by the military services for each test participant.
23 June 1978	DNA accepted NAS protocol for study of the participants in the atmospheric nuclear tests.
13 July 1978	DNA representatives testified at a hearing held by the Subcommittee of the House Committee on Government

	Operations. They discussed DOD research to identify participants in the atmospheric nuclear weapons tests and possible exposures to ionizing radiation resulting from their participation.
March 1979	DNA initiated a notification and medical examination program for all DOD test participants with cumulative doses from atmospheric nuclear testing in excess of 25 rem.
April, May, and August 1979	Subcommittee on Oversight and Investigations, House Committee on Interstate and Foreign Commerce, conducted four hearings to consider health and safety issues related to the atmospheric nuclear testing program. The hearings, directed to civilian residents downwind of the tests, were on 19 April 1979 in Salt Lake City, Utah, 23 April 1979 in Las Vegas, Nevada, and 24 May and 1 August 1979 in Washington, D.C.
May 1979	DNA expanded the notification and medical examination program to include the Desert Rock Volunteer Observers.
8 May 1979	DNA representatives testified at a hearing held by the Subcommittee on Energy, Nuclear Proliferation and Federal Services of the Senate Committee on Governmental Affairs. They identified the progress made by DNA and the service teams to collect data on DOD participants in atmospheric nuclear weapons testing.
June 1979	DNA expanded the notification and medical examination program to include all participants with doses in excess of 5.0 rem during any 12-month period.
15 June 1979	DOD and VA representatives signed a formal Memorandum of Understanding concerning the investigation of ionizing radiation injury claims from veteran atmospheric nuclear test participants.
20 June 1979	DNA representatives testified at a hearing held by the Senate Committee on Veterans Affairs. They discussed the declassification of documents relevant to atmospheric nuclear weapons testing and dose reconstruction for test participants who did not wear badges.
3 October 1979	DNA expanded the NTPR effort to include U.S. service personnel who had participated in the postwar occupation of Hiroshima and Nagasaki, Japan.
August 1980	DNA issued a detailed fact sheet on the U.S. postwar occupation of Hiroshima and Nagasaki.
28 September 1980	The CBS television program "60 Minutes" aired a segment on the NTPR program.

3 October 1980	Preliminary findings of the CDC study concerning the incidence of leukemia among SMOKY participants appeared in the *Journal of the American Medical Association*.
5 March 1981	The ABC television program "20/20" reported on Operation WIGWAM, conducted in the Pacific on 14 May 1955. The report was based on an article on WIGWAM in the January 1981 edition of *New West* magazine.
13-14 May 1981	At the request of DNA, NRC convened a panel to review available data concerning personnel participation in the occupation of Hiroshima and Nagasaki, Japan. The panel subsequently advised DNA that the incidence of multiple myeloma among the occupation forces should be explored.
4 June 1981	VA issued Circular 10-81-99, thereby updating procedures for physical examinations of atmospheric nuclear test participants.
July 1981	DOE opened to the public the Coordination and Information Center, an archives in Las Vegas, Nevada, housing documents pertinent to U.S. nuclear weapons testing and NTPR.
September 1981	DNA published *PLUMBBOB Series, 1957*, the first of the DNA histories on a U.S. atmospheric nuclear test series.
27 October 1981	DNA representatives testified at a hearing held by the Senate Committee on Labor and Human Resources. They commented on proposed Bill S. 1483, which would make the U.S. liable in incidents related to fallout from the atmospheric nuclear weapons tests.
3 November 1981	Congress enacted Public Law 97-72, "Veterans' Health Care, Training, and Small Business Loan Act of 1981," which authorizes the VA to provide hospital and nursing home care and limited outpatient services to veterans exposed to ionizing radiation while participating in U.S. atmospheric nuclear testing or the Hiroshima/Nagasaki occupation. This law does not, however, provide for the care of conditions resulting from causes other than exposure to ionizing radiation.
April 1983	VA Circular 10-83-61 authorized treatment of test participant veterans for any ailment except those that are clearly not radiogenic in origin (e.g., appendicitis and traumatic injury).
18 April 1983	DNA representatives testified at a hearing held by the Senate Committee on Veterans Affairs. They reported on the status of the NTPR program and related matters.
24 May 1983	DNA representatives testified at a hearing held by the Subcommittee on Oversight and Investigations of the House Committee on Veterans' Affairs. They outlined the scope

	and accomplishments of the NTPR program and discussed the Stafford Warren papers and Operation CROSSROADS.
June 1983	NRC completed its "Multiple Myeloma Among Hiroshima/ Nagasaki Veterans," a study concluding that "the reported incidence of nine verified cases of multiple myeloma among U.S. veterans of the occupation forces stationed in or near Hiroshima and Nagasaki constitutes an incidence no greater than that in the general U.S. population." This report was mailed to all Hiroshima/Nagasaki veterans for whom DNA had a current address.
June 1983	DNA and the Navy NTPR mailed information to about 40,000 veterans of atmospheric nuclear weapons testing identifying free medical benefits available to them through VA.
5 August 1983	The results of the updated CDC study of Shot SMOKY participants appeared in the *Journal of American Medical Association*. The conclusions were that participant deaths due to cancer as well as total numbers of cancer cases were slightly less than the statistical norm. The only abnormal finding was a larger number than expected of leukemia cases. This number was attributed primarily to chance.
May 1984	DNA published *Operation CROSSROADS, 1946*, the last of the DNA histories on a U.S. atmospheric nuclear test series.
24 October 1984	Congress enacted Public Law 98-542, "Veterans' Dioxin and Radiation Exposure Compensation Standards Act," which defined rules for adjudicating VA claims and established a panel of experts for addressing scientific issues.
May 1985	NRC published *Mortality of Nuclear Test Participants*, which discussed the results of its study by cause of death of 46,186 participants in the nuclear tests. The study found no consistent evidence of increased deaths from cancer or other diseases for the veterans. It did, however, confirm an excess of leukemia among Shot SMOKY veterans and find a slightly increased number of prostrate cancers among Operation REDWING veterans.
28 May 1985	VA issued Circular 10-85-83, which replaced VA Circular 10-83-61 and provided free medical care for participants in the atmospheric nuclear tests.
7 June 1985	DNA mailed information to about 45,000 veterans of atmospheric nuclear weapons testing outlining the NRC and CDC studies, the efforts of NTPR, and the free medical benefits available to them through VA. DNA also requested comments on its proposed rules for responding to VA claims.

July 1985	The Office of Technology Assessment (OTA) issued its report entitled An Evaluation of the Feasibility of Studying Long-Term Health Effects in Atomic Veterans. OTA concluded that global studies concerning the health of nuclear test participants are not feasible. It suggested, however, that the SMOKY cohort previously studied by the CDC/NRC be researched at 5-year intervals and that a mortality study be conducted of the participants in Operation CROSSROADS.
August 1985	VA published its final rules on adjudicating claims as required by Public Law 98-542.
October 1985	DNA published its final rules on responding to VA claims as required by Public Law 98-542.
8 November 1985	The General Accounting Office (GAO) published its report Operation CROSSROADS: Personnel Radiation Exposure Estimates Should Be Improved. Regarding the CROSSROADS participants, GAO claimed that (1) allowances had not been made for film badge inaccuracies, (2) personnel decontamination procedures were inadequate, and (3) DNA did not adequately evaluate internal radiation exposure.
3 December 1985	President Reagan signed Public Law 99-166, "Veterans Administration Health-Care Amendments of 1985." This law extended certain portions of Public Law 97-72, which provided health care benefits for eligible veterans.
11 December 1985	DNA representatives testified at a hearing held by the Senate Committee on Veterans Affairs. They commented on issues pertaining to the possible radiation exposures received by participants in Operation CROSSROADS, conducted in 1946 at Bikini as the first postwar nuclear test series.
7 February 1986	NAS made public its report entitled Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests. This report reviewed the entire dose reconstruction effort and judged the methodology and processes to have sound scientific merit: "Although the committee concentrated only on methods, it found no evidence that the NTPR teams had been remiss in carrying out their mandate. If any bias exists in the estimates, it is the tendency to overestimate the most likely dose."

APPENDIX B

GLOSSARY

The following technical and organizational terms are used in this volume.

ABSORBED DOSE	The amount of energy absorbed per unit mass of irradiated material. Absorbed dose is measured in rads.
AIR BURST	The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface.
AIR SAMPLING for RADIOACTIVITY	The process of collecting certain volumes of air to determine the level of radioactivity in the air.
ALPHA PARTICLE	A form of particulate radiation emitted from the nuclei of certain radioactive elements. An alpha particle is composed of two neutrons and two protons and is identical to the nucleus of a helium atom, having a double positive charge. An alpha particle cannot penetrate clothing or the outer layer of skin, so it is not an external exposure hazard. Such a particle is extremely hazardous, however, if exposure occurs internally.
ATOM	The smallest particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom. The nucleus is generally composed of uncharged neutrons and positively charged protons. It is surrounded by electrons that carry a negative charge.
ATOMIC ENERGY	Energy released by various nuclear reactions, such as fission, fusion, or radioactive decay. Great amounts of energy are released during fission and fusion processes. It is this energy that makes nuclear weapons far more powerful than conventional explosives. Nuclear energy is another and a more appropriate label for this energy.
BETA BURNS	Skin lesions caused by deposition of beta-emitting fallout particles onto bare human skin.
BETA PARTICLE	A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Physically, the beta particle is identical to an electron moving at high speed.

BIOASSAY	The determination of the concentration of materials, including radioactive materials, within the body by sampling and analyzing tissue or body fluids.
BURST	An explosion or detonation.
CHAIN REACTION	A reaction that stimulates its own repetition, usually referring to fission or fusion reactions.
CLOUD SAMPLING	The process of collecting samples of the cloud resulting from a nuclear detonation to determine the amount of airborne radioactivity, both particulate and gaseous, contained in the cloud. This was usually conducted by specially equipped aircraft.
CLOUD STEM	The visible column of debris (and possibly dust and water droplets) extending upward from the point of burst of a nuclear device.
CLOUD TRACKING	The process of using either radar or aircraft to monitor the drift of a cloud resulting from a nuclear detonation.
CONTAMINATION, RADIOACTIVE	The presence of unwanted radioactive material on or within areas, objects, or persons.
CUMULATIVE DOSE	The total dose resulting from repeated exposure to radiation.
DECAY, RADIOACTIVE	The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays. The radiation is emitted by an unstable isotope. As a result of the emission, the radioactive isotope is converted into a different element that may or may not be radioactive.
DECONTAMINATION	The reduction in the effect of contaminating radioactive material or the removal of contaminating radioactive material from a structure, area, object, or person.
DEVICE, NUCLEAR	A nuclear explosive device, commonly referred to as an atomic or nuclear weapon, engineered to produce a detonation with some predetermined characteristics.
DOSE	See ABSORBED DOSE or DOSE EQUIVALENT.
DOSE EQUIVALENT	The absorbed dose expressed in terms of its biological effect. It is the product of the absorbed dose in rads multiplied by a quality factor and any modifying factors. The dose equivalent is expressed in rem.

DOSIMETER	An instrument for measuring and recording the total accumulated dose of (or exposure to) ionizing radiation. Instruments worn or carried by individuals are called personnel dosimeters.
DOSIMETRY	The theories about and applications of the techniques involved in measuring and recording radiation doses and dose rates. Its practical application includes the use of various types of radiation detection instruments to measure radiation.
EXPOSURE, X or GAMMA RADIATION	A measure of the ionization produced by gamma (or X) rays in air. The exposure rate, exposure per unit of time, is commonly used to indicate the gamma radiation intensity of a source. The unit of exposure is the roentgen (R).
FALLOUT	The descent to the earth's surface of particles contaminated with radioactive material as a result of a nuclear detonation. The term also applies to the contaminated particulate matter itself.
FILE A	The NTPR data base consisting of information extracted from telephone calls to the DNA toll-free lines and from letters drafted by participants in the atmospheric nuclear weapons tests and in the postwar occupation of Hiroshima and Nagasaki.
FILM BADGE	A personnel dosimeter utilizing photographic film to measure the radiation dose received by the wearer. The badge is usually clipped to an outer garment above waist level. The dose is calculated from the degree of film darkening that results from exposure to radiation.
FIREBALL	The luminous sphere of hot gases that forms a few thousandths of a second after a nuclear detonation.
FISSION	The splitting of a heavy nucleus into two or more radioactive nuclei, accompanied by the release of a large amount of energy and generally one or more neutrons and one or more gammas.
FUSION	The formation of a heavier nucleus from two lighter nuclei, accompanied by the release of a large amount of energy.
GAMMA RAYS	A form of electromagnetic radiation emitted spontaneously from the nuclei of certain radioactive elements, often in conjunction with the emisson of alpha or beta particles. Gamma rays also result from other nuclear reactions, such as fission and neutron capture. Gamma rays are identical to X-rays, except that they

	originate within the nucleus. Gamma rays travel great distances in the air and can easily penetrate most substances.
GROUND ZERO (GZ) or SURFACE ZERO (SZ)	The point on the ground vertically below or above the center of a nuclear burst; frequently abbreviated GZ. This is also referred to as surface zero, especially for underwater or overwater bursts.
HALF-LIFE, RADIOLOGICAL	The time required for a radioactive substance to lose half of its activity by radioactive decay.
HEALTH PHYSICS	The branch of radiological science dealing with the protection of personnel from exposure to ionizing radiation.
HEIGHT OF BURST	The height above the earth's surface at which a device is detonated.
HIGH ALTITUDE BURST	A detonation at an altitude over 100,000 feet.
INDUCED RADIOACTIVITY	Radioactivity produced in certain materials as a result of the capture of neutrons. In a nuclear detonation, neutrons induce radioactivity in the weapon debris as well as in the surroundings.
INITIAL NUCLEAR RADIATION	Nuclear radiation (essentially neutrons and gamma rays) emitted from the fireball and the cloud during the first minute after a nuclear explosion. One minute is the time required for the source of part of the radiations (such as fission products in the cloud) to attain such a height that only insignificant amounts of radiation from the cloud reach the earth's surface.
INTENSITY, NUCLEAR RADIATION	The amount of energy of any radiation incident on an area. This term, usually applied to gamma radiation, expresses the exposure rate (in R/hour) at a given location.
IONIZATION	The removal of an electron from an atom, leaving a positively charged ion. The detached electron and the remaining ion are referred to as an ion pair.
IONIZING RADIATION	Electromagnetic radiation (gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, or neutrons) capable of producing ions in its passage through matter.
KILO-	A prefix denoting 1,000. For example, one kiloton means 1,000 tons.
MANHATTAN DISTRICT	A district of the U.S. Army Corps of Engineers, organized in 1942, that developed the atomic bomb.

MEGA-	A prefix denoting 1,000,000. For example, one megaton means 1,000,000 tons.
MONITORING	The procedure or operation of locating and measuring radioactive contamination by means of survey instruments. Persons engaged in this activity are referred to as radiological monitors.
NEUTRON	One of the elementary particles of an atom. Neutrons are uncharged and have a mass number of one. They are used to initiate the fission process, and large numbers of them are produced in fission and fusion processes. They constitute a significant portion of the prompt radiation from both fission and fusion detonations. Neutrons travel great distances in the air and can readily penetrate most substances.
NEVADA TEST SITE (NTS)	The region in southeast Nevada set aside for the continental atmospheric nuclear weapons testing program. Known first as the Nevada Test Site, then as the Nevada Proving Ground (NPG) beginning in early 1952, the site since 1955 has again been called the NTS.
NUCLEAR DETONATION	A general name given to any explosion in which the energy released results from reactions involving atomic nuclei, either fission or fusion or both.
NUCLEAR RADIATION	Radiation emitted from unstable nuclei. Important nuclear radiations are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true. X-rays, for instance, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.
NUCLEAR TEST PERSONNEL REVIEW (NTPR)	An organization established by the Defense Nuclear Agency to conduct a series of wide-ranging actions on behalf of U.S. atmospheric nuclear test participants and veterans of the postwar U.S. occupation of Hiroshima and Nagasaki, Japan.
OFFSITE	The area outside the boundaries of the Nevada Test Site.
ONSITE	The total area encompassed by the Nevada Test Site, including Camp Mercury, Frenchman Flat, Yucca Pass, and Yucca Flat.
PROMPT RADIATION	Radiation emitted from a nuclear detonation within a microsecond of detonation. It consists mainly of neutron and gamma radiation.

RAD	The unit of absorbed radiation dose that represents the absorption of 100 ergs of ionizing radiation per gram of absorbing material, such as body tissue.
RADIATION	The emission and propagation of energy through matter or space. The term includes the propagation of alpha and beta particles, neutrons, photons, and thermal energy.
RADIOACTIVITY	The spontaneous emission of alpha or beta particles, neutrons, or gamma rays from the nuclei of unstable isotopes. As a result of this emission, the radioactive isotope decays into another isotope that may or may not also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.
REM	The unit of dose equivalent, which is the amount of any ionizing radiation that produces the same biological effect as one rad of gamma or X-radiation. The rem is the product of the absorbed dose (rads) times the quality factor and any other modifying factor.
RESIDUAL RADIATION	Nuclear radiation, chiefly beta particles and gamma rays, that persists after the first minute following a nuclear detonation. The radiation is emitted mainly by fission products and materials in which radioactivity has been induced by the capture of neutrons.
RESPIRATOR	A device worn over the mouth and nose to prevent the inhalation of hazardous material.
ROENTGEN	A unit of exposure to gamma radiation or X-radiation. It is the quantity of gamma rays or X-rays that produces 2.08 x 10^9 ion pairs in a cubic centimeter of air at standard temperature and pressure. An exposure of one roentgen is approximately equal to an absorbed dose of one rad in soft tissue.
SHIELDING	Any material or obstruction that absorbs radiation and thus tends to protect personnel from exposure. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed to provide shielding from gamma rays.
SURFACE BURST	The explosion of a nuclear device at a height above the surface less than the radius of the fireball. An explosion in which the device is detonated on the surface is called a contact surface burst or a true surface burst.

THERMONUCLEAR	An adjective referring to the process in which very high temperatures are used to bring about the fusion of hydrogen nuclei with the accompanying liberation of energy. A thermonuclear device is one in which part of the explosive energy results from thermonuclear fusion reactions. The high temperatures required are obtained by means of a fission explosion.
X-RAYS	Penetrating electromagnetic radiation similar to gamma rays but of non-nuclear origin and of lower energy.
YIELD	The total effective energy released in a nuclear detonation. It is usually expressed in terms of the TNT equivalent required to produce the same energy release in an explosion. Nuclear detonation yields are commonly expressed in kilotons or megatons (thousands or millions of tons) of TNT equivalent.

Many of the definitions cited above have been adapted from Glasstone and Dolan; Atomic Energy Commission, Nuclear Terms; and Bureau of Radiological Health Publication Number 2016.

APPENDIX C

LIST OF ABBREVIATIONS AND ACRONYMS

This volume uses the following abbreviations, including the current and commonly accepted designations of LANL, LASL, NTS, and PPG:

AEC	Atomic Energy Commission
AFB	Air Force Base
AFIP	Armed Forces Institute of Pathology
AFNTPR	Air Force Nuclear Test Personnel Review
AFRRI	Armed Forces Radiobiology Research Institute
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
ANL	Argonne National Laboratory
ANTPR	Army Nuclear Test Personnel Review
BIRLS	Beneficiary Identification and Records Locator Subsystem (Veterans Administration)
CDC	Centers for Disease Control
CIC	Coordination and Information Center
CIRRPC	Committee on Interagency Radiation Research and Policy Coordination
CONUS	Continental United States
DMA	Division of Military Application
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
DOE/NVOO	Department of Energy/Nevada Operations Office
DOL	Department of Labor
EG&G	Edgerton, Germeshausen, & Grier, Inc. (former name)
FCNTPR	Field Command Nuclear Test Personnel Review
HAI	History Associates Incorporated
JCS	Joint Chiefs of Staff
LANL	Los Alamos National Laboratory, previously the Los Alamos Scientific Laboratory (LASL)
LLNL	Lawrence Livermore National Laboratory, previously the University of California Radiation Laboratory (UCRL)
MED	Manhattan Engineer District
MCNTPR	Marine Corps Nuclear Test Personnel Review
NAS	National Academy of Sciences
NAAV	National Association of Atomic Veterans
NNTPR	Navy Nuclear Test Personnel Review
NPRC	National Personnel Records Center
NRC	National Research Council (National Academy of Sciences)
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site, known as the Nevada Proving Ground (NPG) prior to 1955
OEHL	Occupational and Environmental Health Laboratory
OTA	Office of Technology Assessment
PPG	Pacific Proving Ground, sometimes called the Enewetak Proving Ground or Bikini Proving Ground
REECo	Reynolds Electrical & Engineering Company, Incorporated
rem	roentgen equivalent man
SWC	Special Weapons Command
VA	Veterans Administration

APPENDIX D

PUBLIC RESOURCES FOR DOCUMENTS ON ATMOSPHERIC NUCLEAR WEAPONS TESTING

Documents pertinent to the continental and oceanic series of atmospheric nuclear tests can be located at the National Technical Information Service (NTIS) and at the Department of Energy Coordination and Information Center (CIC), introduced in section 3.1.2. This appendix provides detail on both of these resources.

D.1 NATIONAL TECHNICAL INFORMATION SERVICE.

The National Technical Information Service, an agency of the Department of Commerce, is the central source for the public sale of Government-sponsored research reports and analyses. The NTIS Bibliographic Data Base consists of documents from a number of Government agencies but primarily from the DOE, DOD, and the National Aeronautics and Space Administration. The agency supplies its customers with about 23,000 information products daily and approximately 4 million documents and microforms annually.

The NTIS information collection comprises over 1 million titles, all of which can be purchased under the provisions of Title 15 U.S. Code 1151-7. This law established NTIS as a clearinghouse for scientific, technical, and engineering information and directed the agency to recover its costs through the sale of information and services.

Documents available for purchase at NTIS include the 41-volume history of atmospheric nuclear weapons testing developed by DNA as part of the NTPR program. Appendix E lists these volumes according to title, DNA number, date of publication, number of pages, NTIS price code, and NTIS order number. Other NTIS materials relevant to the nuclear testing program are the over 1,000 documents declassified by DNA in partial fulfillment of NTPR tasking.

The agency address is: National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. The telephone number (703) 487-4650 should be used when the caller has the NTIS order number and the price code. The caller should dial (703) 487-4780 when he or she does not have this information for a document.

NTIS standard prices for documents and microfiche are identified below. For billing purposes, NTIS accepts the American Express Card, Master and VISA accounts, as well as personal checks. There is a $3.00 handling charge per order.

NTIS DOMESTIC PRICE SCHEDULES EFFECTIVE AS OF JUNE 1986

Price Codes and Prices for Documents

Microfiche and Paper Copy

Price Code	Price
Microfiche	
A01	$ 5.95
Paper Copy	
A02 and A03	$ 9.95
A04 and A05	11.95
A06 through A09	16.95
A10 through A13	22.95
A14 through A17	28.95
A18 through A21	34.95
A22 through A25	40.95

D.2 COORDINATION AND INFORMATION CENTER.

Most of the unclassified documents available at the NTIS are also accessible at the DOE Coordination and Information Center. This section presents information from a DOE fact sheet (dated 16 August 1985) detailing the CIC purposes, scope, and procedures, including the current fee schedule.

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(Abridged)

DEPARTMENT OF ENERGY

COORDINATION AND INFORMATION CENTER

Purpose

The purpose of the Coordination and Information Center is to:

- Collect and consolidate, for long term preservation, all historical documents, records, and data dealing with offsite radioactive fallout from all U.S. testing of nuclear devices
- Provide resources and methods for identification and retrieval of documents based on subject and content
- Allow access to the collected documents by all interested parties, including the general public.

Scope

The CIC, as a publicly accessible facility, contains only unclassified documents. Many formerly classified documents have been declassified or sanitized and are included in the CIC collection. There are no classified documents available at or through the CIC.

The scope of the collection includes:

- Data and documentation on the detection and measurement of radioactive fallout and related factors resulting from nuclear device test activities at the Nevada Test Site, the TRINITY event, the Pacific Proving Grounds, and other on-continent test locations
- Policy documents dealing with procedures and conduct of tests and with public safety considerations and actions
- Published and primary sources describing the development and state-of-knowledge of the health effects of radiation
- Documents dealing with public information as disseminated through such media as pamphlets, news releases, and news publications
- Related studies and reports produced by the scientific and technical field.

Sources and Types of Information

The CIC began document collection in the fall of 1979. Since then it has collected an estimated 125,000 documents. Collection activities are continuing, and it is anticipated that approximately 200,000 documents will ultimately be included in the collection.

To date, document have been received from over 50 individual and agency contributors. The major source of documents have been the Department of Energy (DOE) Headquarters; the DOE Nevada Operations Office; the Las Vegas and Washington, D.C., offices of the Environmental Protection Agency; the Department of Defenses' Defense Nuclear Agency and Defense Technical Information Center; the DOE Technical Information Center in Oak Ridge; the DOE Environmental Measurement Laboratory in New York City; the Los Alamos National Laboratory; the University of California Project 37 Files; the Utah State Archives in Salt Lake City; the Nevada State Archives in Carson City; the Weather Service Nuclear Support Office; and the Technical Library of the Reynolds Electrical and Engineering Company, Inc., at Mercury, Nevada.

The following describes, in general, the content of some of the most significant collections:

- Documents collected from the archives in the Historians Office of the Department of Energy Headquarters focus primarily on the policy and decision making activities of the Atomic Energy Commission. These include the minutes of the AEC and the Advisory Committee for the Division of Biology and Medicine, executive correspondence, secretariat papers, staff papers, and special reports.

- The DOE Nevada Operations files yielded a wide variety of documentation, including operational and administrative orders, reports, procedures, and correspondence regarding conduct of tests.

- The files of Project 37 of the University of California deal with soil sampling and monitoring of select test events within the 250 mile radius of the Nevada Test Site.

- By request of the Health, Education, and Welfare Department, a review of the records from the Washington, D.C., offices of the old Public Health Service was conducted in 1979. This review produced a three volume report, "Effects of Nuclear Weapons Testing on Health Report of the Panel of Experts on the Archives of PHS Documents," which lists approximately 12,000 documents. The three volume report and microfilm copy of all documents listed are in the CIC collection.

- The DOD Defense Nuclear Agency's Nuclear Test Personnel Review program produced a series of summary reports on the Pacific and continental atmospheric weapons tests in which DOD and military personnel participated. The CIC is a repository for the summary reports and for many of the reference documents used as sources.

- In January 1979, at the request of Governor Scott M. Matheson, all Utah State offices surveyed their records and files and produced a collection of documents dealing with fallout, the health effects of ionizing radiation, and related topics. Microfilm copy of this collection is resident in the CIC.

- The CIC collection includes press releases issued by the Department of Energy and predecessor offices as well as an extensive collection of newspaper articles which reflect the concern for public information and the public attitude and knowledge about the testing program in Nevada.

CIC Facilities and Services

The CIC facility provides accommodations for:

- A public reading room where documents of general public interest are available for review
- A research area where requested documents may be used for more in-depth study
- Computer terminals for staff-assisted research of the data base and files
- Printed and microfiche indices to the collection
- Microform reader/printers for review and copy of documents contained only on microform
- Document duplication equipment.

A staff of technical and clerical personnel is available to provide research assistance and access to document.

The Coordination and Information Center is open for visitors from 9:00 a.m. to 4:00 p.m., Monday through Friday. Requests for services should be made to Coordination and Information Center, Reynolds Electrical and Engineering Co., Inc., Post Office Box 14400, Las Vegas, Nevada 89114 or call commercial (702) 295-0731 or FTS 575-0731.

APPENDIX E

DNA NTPR PUBLICATIONS ON THE CONUS AND OCEANIC ATMOSPHERIC NUCLEAR TESTS AS OF 1 MAY 1986

AVAILABILITY INFORMATION

An availability statement is included at the end of the reference citation for those readers who wish to read or obtain copies of source documents.

Source documents bearing an availability statement of NTIS may be purchased from the National Technical Information Service. When ordering by mail or phone, please include both the price code and the NTIS number. The price code appears in parentheses before the NTIS order number.

National Technical Information Service
5285 Port Royal Road — Phone: (703) 487-4650 (Sales Office)
Springfield, VA 22161 — (703) 487-4780 (Identification)

Source documents bearing an availability statement of CIC may be ordered or reviewed at the following address:

Department of Energy
Coordination and Information Center
(Operated by Reynolds Electrical & Engineering Co., Inc.)
3084 S. Highland
P.O. Box 14400 — Phone: (702) 295-0731
Las Vegas, NV 89114-4400 — FTS: (702) 575-0731

NTPR PUBLICATIONS ON THE CONUS AND OCEANIC ATMOSPHERIC NUCLEAR TESTS AS OF 1 MAY 1986

I GENERAL

Reference Manual. DNA-6031F. Apr 83. 224 p. (A10) AD/A136 818.*

"Radiac Instruments and Film Badges Used at Atmospheric Nuclear Tests." DNA-TR-84-338. Sep 85. 84 p. (A05) AD/A163 137.*

II HISTORIES

A Continental US Tests

"Project TRINITY, 1945-1946." DNA-6028F. Jan 83. 74 p. (A04) AD/A128 035.*

Operation RANGER--Shots ABLE, BAKER, EASY, BAKER-2, FOX--25 January - 6 February 1951. DNA-6022F. Feb 82. 182 p. (A09) AD/A118 684.*

Operation BUSTER-JANGLE, 1951. DNA-6023F. Jun 82. 190 p. (A09) AD/A123 441.*

"Shots ABLE - EASY: The First Five Tests of the BUSTER-JANGLE Series, 22 October - 5 November 1951." DNA-6024F. Jun 82. 140 p. (A07) AD/A122 358.*

"Shots SUGAR and UNCLE: The Final Tests of the BUSTER-JANGLE Series, 19 November - 29 November 1951." Jun 82. 132 p. (A07) AD/A122 243.*

Operation TUMBLER-SNAPPER, 1952. DNA-6019F. Jun 82. 218 p. (A10) AD/A122 242.*

"Shots ABLE, BAKER, CHARLIE & DOG: The First Tests of the TUMBLER-SNAPPER Series, 1 April - 1 May 1952." DNA-6020F. Jun 82. 232 p. (A11) AD/A122 241.*

"Shots EASY, FOX, GEORGE & HOW: The Final Tests of the TUMBLER-SNAPPER Series, 7 May - 5 June 1952." DNA-6021F. Jun 82. 178 p. (A09) AD/A122 240.*

Operation UPSHOT-KNOTHOLE, 1953. DNA-6014F. Jan 82. 266 p. (A12) AD/A121 624.*

See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.

"Shots ANNIE - RAY: The First Five Tests of the UPSHOT-KNOTHOLE Series, 17 March - 11 April 1953." DNA-6017F. Jan 82. 208 p. (A10) AD/A121 635.*

"Shot BADGER--A Test of the UPSHOT-KNOTHOLE Series, 18 April 1953." DNA-6015F. Jan 82. 100 p. (A06) AD/A121 671.*

"Shot SIMON--A Test of the UPSHOT-KNOTHOLE Series, 25 April 1953." DNA-6016F. Jan 82. 94 p. (A05) AD/A121 667.*

"Shots ENCORE - CLIMAX: The Final Four Tests of the UPSHOT-KNOTHOLE Series." DNA-6018F. Jan 82. 232 p. (A11) AD/A121 634.*

Operation TEAPOT, 1955. DNA-6009F. Nov 81. 274 p. (A12) AD/A113 537.*

"Shots WASP - HORNET: The First Five TEAPOT Tests, 18 February - 18 March 1955." DNA-6010F. Nov 81. 188 p. (A09) AD/A114 080.*

"Shot BEE--A Test of the TEAPOT Series, 22 March 1955." DNA-6011F. Nov 81. 86 p. (A05) AD/A113 539.*

"Shot APPLE 2--A Test of the TEAPOT Series, 5 May 1955." DNA-6012F. Nov 81. 104 p. (A06) AD/A113 538.*

"Shots ESS through MET and Shot ZUCCHINI: The Final TEAPOT Tests, 23 March - 15 May 1955." DNA-6013F. Nov 81. 260 p. (A12) AD/A114 082.*

PLUMBBOB Series, 1957. DNA-6005F. Sep 81. 312 p. (A14) AD/A107 317.*

"Shots BOLTZMANN - WILSON: The First Four Tests of the PLUMBBOB Series, 28 May - 18 June 1957." DNA-6008F. Sep 81. 144 p. (A07) AD/A118 681.*

"Shot PRISCILLA--A Test of the PLUMBBOB Series, 24 June 1957." DNA-6003F. Feb 81. 104 p. (A06) AD/A105 674.*

"Shot HOOD--A Test of the PLUMBBOB Series [5 July 1957.]" DNA-6002F (Rev). 13 May 83. 108 p. (A06) AD/A138 287.*

"Shots DIABLO - FRANKLIN PRIME: The Mid-Series Tests of the PLUMBBOB Series, 15 July - 30 August 1957." DNA-6006F. Sep 81. 202 p. (A10) AD/A118 683.*

See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.

"Shot SMOKY--A Test of the PLUMBBOB Series, 31 August 1957." DNA-6004F. May 81. 156 p. (A08) AD/A103 828.*

"Shot GALILEO--A Test of the PLUMBBOB Series, 2 September 1957." DNA-6001F. Feb 81. 84 p. (A05) AD/A103 829.*

"Shots WHEELER - MORGAN: The Final Eight Tests of the PLUMBBOB Series, 6 September - 7 October 1957." DNA-6007F. Sep 81. 146 p. (A07) AD/A118 680.*

"Safety Experiments, November 1955 - March 1958." DNA-6030F. Aug 82. 78 p. (A05) AD/A123 423.*

Operation HARDTACK II, 1958. DNA-6026F. Dec 82. 242 p. (A11) AD/A130 929.*

Operation DOMINIC II--Shots LITTLE FELLER II, JOHNIE BOY, SMALL BOY, LITTLE FELLER I--7 July - 17 July 1962. DNA-6027F. Jan 83. 218 p. (A10) AD/A128 367.*

"Projects GNOME and SEDAN: The PLOWSHARE Program." DNA-6029F. Mar 83. 183 p. (A07) AD/A130 165.*

B Oceanic Tests

Operation CROSSROADS, 1946. DNA-6032F. May 84. 568 p. (A24) AD/A146 562.*

Operation SANDSTONE, 1948. DNA-6033F. Dec 83. 222 p. (A10) AD/A139 151.*

Operation GREENHOUSE, 1951. DNA-6034. Jun 83. 334 p. (A15) AD/A134 735.*

Operation IVY, 1952. DNA-6036F. Dec 82. 364 p. (A16) AD/A128 082.*

CASTLE Series, 1954. DNA-6035F. Apr 82. 530 p. (A23) AD/A117 574.*

Operation WIGWAM (Series Volume). DNA-6000F. Sep 81. 262 p. (A12) AD/A105 685.*

Operation HARDTACK I, 1958. DNA-6038F. Dec 82. 474 p. (A20) AD/A136 819.*

See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.

Operation ARGUS, 1958. DNA-6039F. Apr 82. 138 p. (A07) AD/A 122 341.*

Operation DOMINIC I, 1962. DNA-6040. Feb 83. 436 p. (A19) AD/A136 820.*

III DOSE RECONSTRUCTION DOCUMENTS

A World War II

"Radiation Dose Reconstruction U.S. Occupation Forces in Hiroshima and Nagasaki, Japan, 1945-1946." DNA 5512F. Aug 80. 80 p. (A05) AD/A097 038.*

B Continental Tests

"Analysis of Radiation Exposures for Observers and Maneuver Troops, Exercise Desert Rock IV, Operation TUMBLER-SNAPPER." DNA-TR-85-277. Aug 85.**

"Analysis of Radiation Exposure, 2nd Marine Provisional Atomic Exercise Brigade, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE." DNA-TR-82-03. Feb 82. 54 p. (A04) AD/A124 279.*

"Analysis of Radiation Exposure for Maneuver Units, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE." DNA-TR-84-303. Aug 84. 67 p. (A04)AD/A168 116.**

"Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE." DNA-5742F. Apr 81. 124 p. (A06) AD/A116 921.*

"Analysis of Radiation Exposure, Task Force RAZOR, Exercise Desert Rock VI, Operation TEAPOT." DNA-TR-83-07. Jul 83. 68 p. (A04) AD/A152 997.*

"Analysis of Radiation Exposure, Third Marine Corps Provisional Atomic Exercise Brigade, Exercise Desert Rock VI, Operation TEAPOT." DNA-TR-84-13. Feb 84. 50 p. (A03) AD/A152 189.*

"Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock VI, Operation TEAPOT." DNA-5354F. Jul 80. 98 p. (A05) AD/A121 701.*

"Analysis of Radiation Exposure for Task Force WARRIOR, Shot SMOKY, Exercise Desert Rock VII-VIII, Operation PLUMBBOB." DNA-4747F. May 79. 114 p. (A06) AD/A070 239.*

"Analysis of Radiation Exposure for Task Force BIG BANG, Shot GALILEO, Exercise Desert Rock VII-VIII, Operation PLUMBBOB." DNA-4772F. Apr 80. 94 p. (A05) AD/A085 801.*

"Analysis of Radiation Exposure 4th Marine Corps Provisional Atomic Exercise Brigade, Exercise Desert Rock VII, Operation PLUMBBOB." DNA-5774F. Jun 81. 80 p. (A05) AD/A122 204.*

See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.
**Will be available from NTIS and CIC in 1986 or 1987.

C Oceanic Tests

Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS. VOL 1: "Basic Report." DNA-TR-82-05-VI. Mar 82. 168 p. (A08) AD/A152 702.*

__________. Vol 2: "(Appendix A) Target Ships." DNA-TR-82-05-V2. Mar 82. 186 p. (A09) AD/B090 882.**

__________. Vol 3: "(Appendix B) Support Ships." DNA-TR-82-05-V3. Mar 82. 450 p. (A19) AD/B090 883.**

"Analysis of Radiation Exposure for Naval Personnel at Operation SANDSTONE." DNA-TR-83-13. Aug 83. 50 p. (A03) AD/A152 188.*

"Analysis of Radiation Exposure for Naval Personnel at Operation GREENHOUSE." DNA-TR-82-15. Jul 82. 130 p. (A07) AD/A151 621.*

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See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk. Also available at CIC.
**Will be available from NTIS and CIC in 1986 or 1987.

APPENDIX F

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